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COMMENTS

BY

THE COMMITTEE OF THE RATEPAYING ENGINEERS

ON THE

REPORT

ON

AQUEDUCT ENLARGEMENT
MONTREAL WATER WORKS

BY THE

BOARD OF ENGINEERS

ALSO

CERTAIN OTHER DOCUMENTS IN CONNECTION

WITH THE AQUEDUCT ENLARGEMENT.

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COMMENTS BY THE COMMITTEE

OF THE

RATEPAYING ENGINEERS

ON

"REPORT ON THE AQUEDUCT ENLARGEMENT, MONTREAL WATER WORKS,

BY THE

BOARD OF ENGINEERS,

DATED APRIL 30TH, 1917."

TO MONTREAL, JULY 5TH, 1917.

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE BOARD OF COMMISSIONERS
OF THE CITY OF MONTREAL,
L. N. SÉNÉCAL, ESQ., SECRETARY.

AND TO

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE CITY COUNCIL
OF THE CITY OF MONTREAL,
THE HONOURABLE L. O. DAVID, CITY CLERK.

Gentlemen:—

The Ratepaying Engineers of the City of Montreal, who submitted to the City on November 20th, 1916, the report of their Committee, now have the honour to forward to you, the Comments by their Committee on the "Report on the Aqueduct Enlargement, Montreal Water Works, by the Board of Engineers, dated April 30th, 1917." These Comments were submitted at a special meeting duly called and organised for the purpose of receiving and considering them, and received the unanimous approval of the meeting. It was resolved to submit the Comments, together with copies of certain other documents, to the Board of Commissioners and to the City Council, and, in accordance with my instructions, I therefore take pleasure in so doing.

Respectfully submitted,

(Signed) FREDERICK B. BROWN,
Secretary of the meeting of Ratepaying Engineers.

MONTREAL, JUNE, 30TH, 1917.

TO

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE BOARD OF COMMISSIONERS
OF THE CITY OF MONTREAL,

L. N. SENECAL, ESQ., SECRETARY.

AND TO

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE CITY COUNCIL
OF THE CITY OF MONTREAL,

THE HONOURABLE L. O. DAVID, CITY CLERK,

Gentlemen:—

Following the receipt of your letter of 25th May, 1917, undertaking to let us have details of the estimates in the report of the Board of Engineers, dated April 30th, 1917, we have recently received from the City Hall certain pages of details of the report. Having studied these in conjunction with the report, we now beg to submit our comments thereon, as promised.

Summing up our conclusions we may say that to us it is evident that the report of the Board of Engineers agrees in almost every main conclusion with our report submitted last November.

The following contentions of our report are clearly support

(a) *The project as designed is condemned.*

(b) *Ice troubles are admitted to the degree that it is estimated the plant be completely shut down for an average yearly period equivalen 2.4 months.*

(c) *Radical changes in design, at greatly increased cost, are shown to necessary to obtain the amount of power claimed by the City.*

(d) *Purchased power or steam-generated power is shown to be mu cheaper than that which could be produced by the aqueduct.*

(e) *No power from the aqueduct would be available for lighting the Cit*

(f) *The capital costs and annual charges are shown to be greatly in excess of the estimates made by the City.*

The following is a brief comparison, by means of parallel columns, of statements made regarding the various features of the Montreal Aqueduct Power Development Scheme.

The first column is based on published statements by the City up to the end of 1916.

The second column is based on the "Report by Ratepaying Engineers", dated November, 1916.

The third column is based on the "Report on Aqueduct Enlargement, Montreal Water Works" by the Board of Engineers, Messrs. Vautelet, St. Laurent and McRae, dated April 30th, 1917.

A COMPARISON OF STATEMENTS

ON

THE AQUEDUCT QUESTION.

1.—Power obtainable from the Enlarged Aqueduct in Electrical Horse-Power.

The City	The Ratepaying Engineers	The Board
Winter minimum, 9,000. Summer minimum, 18,000. Yearly average minimum, 14,000.	Maximum as designed, 7,000.	"Winter, 5,600. Summer, 8,900". (p. 22) With radical alterations and additions, 9,750.

2.—Probable Ice Troubles in Operation.

The City	The Ratepaying Engineers	The Board
Stated frequently that there would be no ice troubles.	Stated that "serious operating troubles due to ice are inevitable."	States that there will be ice troubles, "equivalent to a complete shut down for 2.4 months each year". (p. 11)

3.—Capital Cost of the Project.

The City	The Ratepaying Engineers	The Board
Variously stated the cost from $2,500,000 to $9,500,000.	Gave the cost as over $10,600,000. (All data for complete estimates were not then available.)	Gives the cost as over $10,600,000, but did not include in the cost certain important items amounting to about $1,400,000, which would make the total cost at least $12,000,000.

4.—Annual Unit Cost of Power from Aqueduct.

The City	The Ratepaying Engineers	The B
Variously stated cost from $13.33 to $40.00 per horse-power per annum.	Said this cost would be $108.00 per electrical horse-power per annum, including sinking fund and depreciation.	Gives this cos per theoret power. (Thi alent to $76.0 ical horse po this cost the B not include sin and depreciati based on a cap of $10,600,000. on a capital $12,000,000 a cluding sinking and depreciatio annual unit cost $100.00 per ele horse-power.)

5.—Study of Project as a Whole previous to Board's Investigat

The City	The Ratepaying Engineers	The Board
Frequently stated that project had been studied as a whole.	Always stated that "project had never been studied as a whole."	Would not answer t question when put Mr. Commissioner V leneuve.

6.—The Necessity for the Undertaking.

The City	The Ratepaying Engineers	The Board
Undertook the present project and declared it very advantageous.	Stated that "the capacity of the original aqueduct was sufficient for three times the present population served, if used for water supply only, and not for hydraulic power" and also that "the present project should never have been started".	Says: — "Had the old aqueduct been left as it was, simply as a supply to the steam pumps, a steam plant would have been a most attractive proposition". (p. 39)

7.—Proposed Completion of Work.

The City	The Ratepaying Engineers	The Board
Persists in continuing, extending and completing the work in spite of protests.	Stated that "all thought of completing the project, along the present lines, should be abandoned".	Stated that the present scheme "is the one to which exception has been taken, and we agree that it should not be proceeded with as outlined. It could not have developed the expected power." (p. 38). The Board does not recommend completion of the project, even after radical modifications.

8.—Solution of the Problem.

The City	The Ratepaying Engineers	The Board
Stated that aqueduct power is the cheapest and best, and recommends completion of project.	Demonstrated the economy of abandoning the project as designed, making the most advantageous use of the work done and purchasing the balance of power or generating it by steam power.	Does not make any definite recommendation for the solution of the problem, except that firm bids on electric power be asked for.

9.—Possibility of Lighting the City Streets by Power from the Aqueduct.

The City	The Ratepaying Engineers	The Board
Stated that power from the aqueduct would be available for lighting the streets, with a surplus of power for sale.	Showed that lighting the streets with power from the aqueduct is impracticable.	Shows that no aqueduct power would be available for lighting streets. (p. 33)

The above comparison shows a general concurrence by the Board of Engineers with the Conclusions of the Ratepaying Engineers.

It is important to note that:—

I. It was only after the protest by the Ratepaying Engineers in April, 1916, that the City began serious studies of the whole project.

II. After the report by the Ratepaying Engineers in November, 1916, the City proposed radical changes in design at additional cost, to meet some of the objections raised. The Board's investigation and report show that further changes in design must be made involving over a million dollars additional cost before the amount of water power claimed by the City could be approximated.

III. The project as proposed by the City is strongly condemned by the Board.

IV. The whole project has become so badly muddled that after a long investigation the Board is unable to recommend a definite course of action, but merely recommends asking tenders for electric power and making further studies.

The resolution of February 6th, 1917, appointing the Board, called for a comparison between the report of the Ratepaying Engineers made in November, 1916, at the request of the City Council, and the different reports of the City Engineer. This comparison has not been made.

This resolution stipulated that a complete study of the proposed development was to have been undertaken, and a report made "as to whether the development is feasible, practical and advantageous, and to advise the City on its advantages and disadvantages, with every recommendation which they (the Board of Engineers) will judge proper to make to the City". It cannot be said that this has been done.

Mr. Commissioner Ross's letter to the Board of Engineers dated February 16th, 1917, apparently advised the Board to disregard the reports referred to in the resolution of February 6th, 1917, but suggested that the Board advise the City as to the right and wisest course for the City now to follow from a business point of view. The Board apparently accepted this letter from one of the Commissioners as instructions overriding a resolution of the City, but failed to make definite recommendations as to the right and wisest course for the City to follow.

In the report and the detail figures sent to the City by the Board certain items are omitted which are clearly chargeable to the capital cost of the aqueduct enlargement. The excess costs of the present steam

pumping over that formerly done by the old aqueduct from 1907 until the completion of construction work, the repairs to the lateral conduit after the break in 1913 which was due to the construction work on the aqueduct, the emergency water supply from the Lachine Canal in this connection, the cost of ten bridges, and certain interest charges during construction, in all amounting to about $1,400,000,00 are omitted. This makes the total cost $12,000,000.00. This figure might easily reach $14,000,000.00 if the cost of all work on the boulevards be included and if any substantial portion of the claims of the Cook Construction Company be allowed.

In comparing the annual unit costs of power purchased with the unit cost of power developed, the Board does not place them on the same basis for comparison. The only proper basis for comparison is for power available as "electrical horse-power" delivered on the switchboard at the Atwater Avenue plant, whether produced by the water in the aqueduct, or purchased in the ordinary commercial way as electrical power, or produced from a steam-electric plant.

As shown on page 14 of the Board's report, only three-quarters of the theoretical water power is available as electric power at the switchboard after deducting the various losses through the water wheels and generators, and therefore in making a comparison with purchased power on a unit basis only three-quarters of the theoretical water horse-power should be considered. In the table of unit costs on page 38 of the Board's report, the cost under Scheme II, is given as $56.90 per theoretical water horse-power per year. This is equivalent to about $76.00 per electrical horse-power per year. In the same table purchased electrical horse-power at $25.00 gives a total annual unit cost of $62.47 per electrical horse-power, or, on a proper basis of comparison, a difference of nearly $14.00 per horse-power per year in favour of purchased power. This practically agrees with the relation of the total figures given on page 35 of the report where the total costs of developed aqueduct power under Scheme II are given as $740,000.00 per year and the total costs of purchased power are less and are given as $656,000.00 per year.

In the Board's calculations of annual costs of power there is no provision made for sinking fund nor for depreciation. Based on the capital expenditure of $12,000,000.00 and with proper allowances for sinking fund and depreciation the total annual operating costs and fixed charges would amount to at least $1,000,000.00, equivalent to over $100.00 per electrical horse-power.

In view of the foregoing there appears to be no justification for the statement on page 41:—"Under ordinary circumstances and with the figures now before us, we would have no hesitation in recommending the adoption of Scheme II with provision for Boulevards, **as its cost of operation per h.-p. per year is the lowest.**" If all cost items are included, either purchased power or steam generated power is much cheaper than water power developed under Scheme II.

A supplementary resolution of the City dated 26th February, 1917, voted an additional credit to the Board on the understanding that the Board was to answer questions submitted in writting by Commissioners or Aldermen. Mr. Commissioner Villeneuve, whose various published commentaries on the aqueduct question during the past year have shown his great interest in this important matter, submitted seven questions on April 30th, 1917, with a definite request for specific replies. In a letter dated May 10th, 1917, submitting their report to the City, the Board referred to these questions but did not reply to them except to say that the information would be found in the report.

After a study of the report we conclude that three or perhaps four of Mr. Villeneuve's questions are fairly covered by the report, but we cannot say this of the others.

In an interview at the City Hall, June 6th, 1917, the Board replied verbally to a number of other questions put to them; and we conclude from the answers as submitted to us that no well defined course of action was then recommended.

As the solution of the problem at the present time, we now urge once more that the proper course for the City to follow is to immediately stop all work on the enlargement of the aqueduct as contemplated, make the most advantageous use of the work done and purchase the balance of the electrical power required or generate it by means of a steam plant. The "most advantageous use of the work done" at the aqueduct might possibly entail the construction of a comparatively small hydro-electric plant, to be operated during the summer, in conjunction with power purchased or produced by steam, so as to keep the load factor high and constant and to take the summer pumping peak load. The size of the plant suggested should not be greater than is necessary to take care of the difference between average and peak pumping requirements or about one-third of the total power required. On this basis the size of the suggested plant should not exceed 3,500 electrical horse-power, and the economical size might prove to be between 3,000 and 2,000 electrical horse-power, or even less, depending on the terms of the power contract entered into.

The financial position of Montreal is deplorable. The necessary funds are not authorized nor available to complete the aqueduct power development project. The incompetence, or whatever it may be, that has permitted the wasting of millions in this one scheme alone is sufficient to shake the confidence of any banker or investor with regard to Montreal securities. The ratepayers of the City have the right to expect that value be obtained for all monies expended, and investors in our municipal securities have the right to know that their investment is sound and that it has been protected by works carried out along true economic lines, which is far from being the case in the present instance.

The Committee of the Ratepaying Engineers, having submitted these comments, feel that they have fulfilled their duty as citizens, and completed the work they undertook in the interest of the tax payers and at the request of the City Council.

We are pleased that our opinions have been so strongly supported by your Board of Engineers, and that our criticisms of the aqueduct power scheme have been fully justified.

We have the honour to be, gentlemen,

The Committee of the Ratepaying Engineers,

(Signed) W. F. TYE

Chairman,

(Signed) JOHN KENNEDY
(Signed) ERNEST MARCEAU
(Signed) J. A. JAMIESON
(Signed) R. A. ROSS
(Signed) ARTHUR SURVEYER
(Signed) WALTER J. FRANCIS

Secretary.

Read and approved at a meeting of the Ratepaying Engineers, held in Montreal on the 5th day of July, 1917.

(Signed) FREDERICK B. BROWN,
Secretary of Meeting.

MEMORANDUM OF PRINCIPAL DATES IN CONNECTION WITH AQUEDUCT CONTROVERSY

May 1913	Staff article in **"Montreal Herald"** questioning project. Later, this was vehemently contradicted by Mr. Janin.
July 1913	**Cook Construction Co.** began on present enlargment.
February 1914	**Jamieson, Lea and Heckle,** City Commission on conduit break, urged appointment of commission to investigate entire aqueduct project. This was again opposed by Mr. Janin.
July 1915	**Council of Canadian Society of Civil Engineers** asked for investigation of project by commission.
August 1915	**Board of Trade** approved of request of Council of Canadian Society of Civil Engineers.
October 1915	**Council of Canadian Society of Civil Engineers** repeated request.
November 1915	**"Canadian Engineer"** published a condemnatory article on waterworks situation.
April 1916	**Ratepaying Engineers** requested commission to investigate waterworks.
June 1916	**City Engi er** reported to President of Canadian Manufacturers' Association endorsing Aqueduct development, following the appearance of a delegation of ratepayers at City Hall.
June 1916	**Ratepaying Engineers** undertook to report on project free of charge.
July 1916	**Commissioner Villeneuve** presented a report condemning project.
November 1916	**Ratepaying Engineers** submitted a report condemning project.
December 1916	**City Engineer** submitted a report "in complete contradiction" of report of Ratepaying Engineers, and asked for Board of Investigation.
February 1917	**Board of Engineers** appointed to make study of whole matter.
May 1917	**Board of Engineers** presented report dated April 30, 1917, condemning project as designed but making no definite recommendation except to get tenders for purchased power.
July 1917	**Ratepaying Engineers** submitted comments, dated June 30, 1917, urging prompt action and outlining solution of problem.

EXTRACT
FROM MINUTES OF A MEETING OF THE BOARD OF COMMISSIONERS HELD ON THE 6th DAY OF FEBRUARY, 1917 (A. M.)

No. 29207.

Whereas the ratepaying engineers of the City have, on the 20th November, 1916, sent to the City a report on the Montreal Aqueduct;

Whereas, by this report, it is recommended to the City to abandon all idea of completing the proposed hydraulic development;

Because it will not produce the expected power;

Because frasil ice might cause a complete stoppage of the power house;

Because it would be more advantageous for the City to purchase the necessary electrical energy;

Whereas the Council has on February 5th, 1917, voted a sum of $5,000.00 to pay the costs of an expertise to be made by independent engineers on the reports of the ratepaying engineers and of the City Engineer;

On motion of Mr. Commissioner Coté,
Seconded by Mr. Commissioner Ross,
It is

Resolved: To ask Messrs. H. E. Vautelet, A. St. Laurent and John McRea to study the proposed hydraulic development, and to report as soon as possible;

As to whether the development is feasible, practical and advantageous, and to advise the City on its advantages and disadvantages, with every recommendation which they will judge proper to make to the City;
It is also

Resolved: That fees of $100.00 shall be paid to each of these experts for each day that they will be employed in preparing or making the report which is asked of them, and that their out-of-pocket expenses will be repaid to them.

(Certified)

(Signed) L. N. Sénécal.
Secretary.

CITY HALL

Messrs: Montreal, February 16th, 1917.

Arthur St. Laurent C. E.
John B. McRea, C. E.
H. E. Vautelet, C. E.

Gentlemen:

Re Aqueduct Project comprising increased Water Supply and Power Development

Will you permit me to address you frankly in regard to the above?

In my opinion there is no question of greater importance to the City of Montreal than that involving decision as to carrying to completion, as designed, or modifying or abandoning the Aqueduct project—and for that reason I feel that you are assuming a most serious responsibility in undertaking to advise us as to the course the City administration should follow.

In the light of the report you may submit, the Commissioners may have to decide, either that the cost of the project to date is to a great extent lost money, or that further expenditure towards the completion of the project, as designed or modified, is justifiable and should prove a profitable investment.

I would like, therefore, to ask whether or not the amount of remuneration ($5,000.00) voted for your services is at all adequate, in view of the time and attention you must devote to the solution of the problem and the necessity for your giving the question closest study, entailing examination of the works, plans, figures—in fact all data, both engineering and financial, pertaining thereto.

Your professional reputation and the city's vital interests are at stake, and I should prefer to recommend the voting, from time to time, of sums sufficient to indemnity you for devoting not days only, but weeks or months attention, if necessary, to this question.

May I suggest that you will not give too much attention to the views and arguments of the ratepaying Engineers' report or to our Chief Engineer's reply thereto, although points are therein raised which should be dealt with, but that you will make an absolutely independent examination into the matter, and in your report advise the City as to what may be, in your opinion, the right course to follow, from a business point of view.

Whether the project as initiated was sound or not is a matter for academic discussion only,—the live question is: what is the wisest course for the city now to follow?

Yours faithfully,
(Signed) A. Guy Ross,
Commissioner.

EXTRACT

FROM THE MINUTES OF A SPECIAL MEETING OF THE MUNICIPAL COUNCIL OF MONTREAL, HELD ON MONDAY, 26th, FEBRUARY, 1917.

There was submitted and read the following report of the Board of Commissioners voting an additional credit of $5,000.00 for the fees of the experts in the matter of the Aqueduct improvements.

"The Board of Commissioners

"has the honour to report,

"That it has taken into consideration the attached report of the "Chief Engineer recommending the vote of an additional credit of $5,000.00 "to pay the fees of the experts charged with studying the question of the "improvements to the Montreal Auqeduct.

"Your Board approves the said report and recommends "to vote for this purpose the said sum of $5,000.00, to be "charged to the Reserve Fund.

"Respectfully submitted

"(Signed) Mederic Martin
"E. W. Villeneuve
"J. Ainey
"A. G. Ross

"Certified

"(Signed) J. Pelletier,
"C. and A. of the C."

Alderman Larivière proposed,
Seconded by Alderman Ward.

That the said report be received and adopted with the express condition that all of the Commissioners and all of the members of the Council may, in writing, ask the experts who have been named to study the question of the Aqueduct all questions which they believe necessary to know exactly the value and expediency of the enlargement of the Aqueduct and of the creation of the motive power, and that the said experts be held to reply to these questions.

The said motion being put to the vote, it was adopted by the affirmative vote of all the members of Council, and it is

Resolved: Accordingly.

Certified

(Signed) René Bauset,
Assistant City Clerk.

Note:—Further credits were voted from time to time making a total amount of $20,000.00 paid to the Board up to June, 1917.

OFFICE OF THE BOARD OF COMMISSIONERS

City Hall, Montreal, April 30th, 1917

Messrs. Vautelet, Saint Laurent and McRae,
Windsor Hotel,
Montreal.

Gentlemen:

As your report on the Aqueduct Enlargement has not yet been presented, and in virtue of a Resolution of the City Council I am empowered to submit questions to you in regard thereto, and further in view of the fact that your work being now completed these questions will be easy for you to answer, I am enclosing a series of questions for your specific replies in connection with the report which you are about to submit to the City of Montreal on this subject.

Yours very truly,

(Signed) E. W. Villeneuve,

Commissioner.

QUESTIONS SUBMITTED BY COMMISSIONER VILLENEUVE RE AQUEDUCT ENLARGEMENT

1—Should the present project have been started?

2—Has the project ever been studied as a whole?

3—What was the capacity of the original aqueduct for use for the supply of water only, and not for hydraulic power?

4—In your opinion would there be difficulty from frasil or other ice, and if so for what lenght of time during each year?

5—Is the present project as placed before you reasonable in design, and properly proportioned in its several parts?

6—What will be the cost in dollars for pumping the amount of water which will be required by the city during the next forty years, by the purchase of power?

7—Should the project be completed as proposed by the City Engineers, November 1st, 1916?

Montreal, May 10th, 1917.

To the Chairman and Members of the Board of Commissioners.
City Hall, Montreal.

Gentlemen:

We have to-day placed in the hands of your Secretary, under sealed cover, 10 French and 12 English copies of our Report on the Aqueduct Power Project, dated 30th April, as per commission issued to us by your Resolution of the 6th of February, 1917.

We have endeavoured to study fully the whole question under its various aspec , and we believe that the Report contains also the information required by Mr. Commissioner E. W. Villeneuve, as per questions submitted by him.

Now that the work connected with our report has been completed, should there be any particular questions to answer we will gladly do so.

We have avoided to overload our Report with too many details but all Hydraulic Data, information collected, as also all figures and detail calculations of Capital Costs and Costs of Operation, etc., are contained in six folios with index, which will be handed to your Chief Engineer.

We attach to this letter copy of the correspondence with the Electric Power Companies of Montreal, at the request of Mr. Commissioner E. W. Villeneuve, as per his letter of March 16th last, copy of which is also attached.

We thank you most cordially for the confidence placed in us, and we are indebted to all the officers and employees of the city, from whom we have had to secure information, for their constant kindness and courtesy to us during our investigation.

We have the honour to be,

Gentlemen,

Your obedient servants,

(Signed) H. E. Vautelet,
Chairman,
" J. B. McRae,
" A. St. Laurent.

REPORT

ON

AQUEDUCT ENLARGEMENT

MONTREAL WATER WORKS

BY THE

BOARD OF ENGINEERS

NOTE:—THE HEAVY PAGE NUMBERS IN THIS REPORT CORRESPOND TO THAT IN THE ORIGINAL ENGLISH TYPEWRITTEN COPY SUBMITTED TO THE CITY.

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PLANS

MONTREAL, APRIL 30TH, 1917.

TO

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE BOARD OF COMMISSIONERS
OF THE CITY OF MONTREAL,

L. N. SENECAL, ESQ., SECRETARY,

AND TO

HIS WORSHIP THE MAYOR
AND THE MEMBERS OF THE CITY COUNCIL
OF THE CITY OF MONTREAL,

THE HONOURABLE L. O. DAVID, CITY CLERK.

Gentlemen,

We, the undersigned, by virtue of the duties assigned to us, by a Resolution of your Board, passed on the 6th of February, 1917, have the honour to present herewith, our Report on the City Aqueduct and proposed Power Development.

To avoid any misunderstanding regarding the Report of the Ratepaying Engineers on the Montreal Aqueduct, addressed to you on November 20th, 1916, we quote from a letter received from Mr. Walter J. Francis, Secretary of the Committee of Ratepaying Engineers, on April 24th, 1917:

"I am instructed to write you to express our regret that a "certain erroneous impression seems to prevail regarding the efforts "and conclusions of the Ratepaying Engineers of the City. This "is a matter which you will doubtless remember was discussed with "you when we last met, and we would merely repeat at this time "that our whole object has always been to have the project submitted "to an independent Board of Engineers. The studies which were "forced upon us resulted in our concluding in Conclusions 16 and "22 that 'all thought of completing the work *along the present* "*lines* should be abandoned' and that the best should be made of

"what has been done, by the utilization and judicious adap
"of the present conditions. We never advised the co
"abandonment of the work, and our references to the abando
"were hypothetical and made for the purpose of indicatin
"need of investigation which we had demanded.

"I am instructed to say, on behalf of the Ratepaying Eng
"that, in justice to them, we confidently expect you will
"occasion in your Report, to correct the erroneous impression
"complete abandonment was recommended, as stated in the
"press, and, indeed, even mentioned in the preamble of the o
"resolution appointing your Board."

We do not consider it necessary to present here a full history o
Aqueduct development since its inception, nor do we consider tha
are called upon to do so, in view of the numerous reports already m
to the City, containing complete historical information on the subj

It is, however, desirable, before commencing the discussion of
project, in accordance with the above mentioned Resolution, to giv
brief outline of the undertaking under progress, its present status a
the amount of work already performed, and expenditure in connect
therewith.

Present Project.

The project in course of execution following previous enlargement
consists in the development of the present aqueduct, to such dimensio
and flow capacity as will enable the hydraulic development of *10,000 H.*
for the purpose of providing *electrical horse power* for pumping the wat
supply needed by the City and for street lighting. It will also suppl
the water for the City's fire and domestic services.

Before commencing these later enlargements, a lateral concrete conduit of a maximum capacity of 75,000,000 Imperial gallons per day was built to insure a continuous water supply for the City. A filtration plant with a daily capacity of 50,000,000 Imperial gallons has also been built which it is intended, we are informed, to enlarge to a capacity of 100,000,000 Imperial gallons per day.

The present aqueduct course is followed in its entire length in the scheme of enlargement.

The Intake is situated on the St. Lawrence River about one and one-half miles below the Canadian Pacific Railway Company's bridge, and the Headrace or Canal extends to the present waterworks station, a distance of 5.2 miles, where it is proposed to construct the necessary Power House, for which no designs have as yet been made.

The Headrace has a slope of 3.3 feet for the entire distance, and a bottom width of 163.85 feet. It runs partly in earth and partly in rock material. The bottom Elevation at entrance is 21 feet above City datum. The water surface fluctuates from Elevation 36. to 42.

The Tailrace, which extends from the present Water Works to the St. Lawrence River opposite Nun's Island, has a total length of about 3,300 feet, a slope of 4 feet, and a bottom width of 113.85 feet. The Tailrace excavation will be apparently entirely through earth material. Elevation of the bed at the Outlet is 2 feet above City datum. The water surface fluctuates from Elevation 8 to 20; flood level has been as high as Elevation 28.0.

Both sides of the Entrance Canal, Forebay and Tailrace are lined with concrete retaining walls.

No paving is provided for the earth sections of the Head Canal.

Paving for the bottom of the Tailrace is provided for in the contract, only for the basin below the power house, but we are i that it is intended to pave the whole of the Tailrace, and this will, therefore, be considered as part of the present scheme.

Status of Present Work of Enlargement.

The City Engineer, in a Report to the Board of Commiss dated December 16th, 1916, estimated the total cost of the work completed, at $11,600,537.06 including cost of the work performed November 28th, 1916, covering all contracts and expenditure sin beginning of enlargements.

By deducting from the above the total amount of the co Filtration works, the cost of a pump built in 1908-10 and in thereon, not chargeable to cost of power development proper, the Engineer arrives at the following figures for the Power scheme:

Cost of work done to November 28th, 1916, including interest	$4,013,5
Estimated cost of work yet to be done, including interest	$5,581,6
TOTAL	$9,595,1

The amount of interest included in the Total is $1,404,550.00.

The cost of abandoning the work has been estimated by Mr. Mercie be as follows:—

Work done and interest	$4,013,51
Work to be done, or payment to make, bridges and fences	300,000
10% on balance of Cook's Contract	203,640
Power House and building to use the 7000 H.P. purchased	340,000
Construction of another conduit or protection work	1,000,000
	$5,857,150.

This is exclusive of large claims against the City in connection with this work, and which will require adjustment.

THE PRESENT CONDITION OF THE WORK FOR THE ENTIRE AQUEDUCT IS AS FOLLOWS:—

WORK PERFORMED:

Earth excavation	about	50% done
Rock "	"	90% "
Retaining wall, north side of Entrance canal	"	48% "
" " " South " " " "	"	20% ".
Forebay and Tailrace walls		nil
Power House		"
Entrance Gates, contract yet to be awarded		no work done
Supply conduit		100%
Expropriation of land required for Boulevards, etc		not completed

The result of our studies is presented under the following main headings with such subdivisions of each subject as are necessary for a clear understanding.

1—Method followed in carrying out the investigation.

2—Frazil.

3—Consumption of water by City.

4—Power actually used for Pumping and Lighting.
Future Requirements for Pumping and Lighting.

5—Definition of the term "Horse Power".

6—Project as designed; Hydraulic Data; Velocities.

7—Amount to be spent, if work is now abandoned.

8—Scheme No. 1. Present Scheme.

9—Scheme No. 2. Maximum Power Available.

10—Scheme No. 3. Minimum Power Available.

11—Scheme No. 4. Pumping by Steam.

12—Scheme No. 5. Buying Electric Current.

13—Lighting.

14—Total Cost and Cost of operation of all Schemes.

15—Financial Statement.

16—Remarks on Cost.

17—Recommendations.

METHOD FOLLOWED IN CARRYING OUT THE INVESTIGATION.

THE NEEDS OF THE CITY ARE:

Power for pumping water at Atwater Avenue and Electric curr for water pumping stations such as McTavish Street and Papin Avenue, Sewage Pumping Stations, Filtration Works, and St Lighting.

There are three ways of obtaining the needed power:

1. The establishment of a Hydro-Power Station at Atwater Ave (Schemes I, II and III).
2. Pumping by steam and buying Electric Current for other ne (Scheme IV).
3. Buying Electric Current for all the needs of the City (Scheme

A start has been made towards the carrying out of Scheme I, a the adoption of either Scheme IV or V would necessitate discontinui the works now in course of execution. We, therefore, had to estima the cost of making the Canal fit for such services as may be required.

If the work be discontinued we have to consider two Cases A and

In case A (Schemes IV and V) the banks of the Canal, where wa have not been built, are simply trimmed to a natural slope, without a attempt to secure straight side lines or regular curves, cutting down t expenditure for this purpose as low as possible, leaving the Tailrace its present state.

In case B (Scheme III) to develop Power, the banks of the Can are sloped in straight lines and regular curves to ease off the flow, an the Tailrace is enlarged to accommodate the discharge through th Headrace.

The cost of case A was found to be $5,895,000. and the amount o interest charged amounts to $1,072,948.

This amount of $5,895,000. has, therefore, to be added to the cos of pumping by steam or by electric current.

If the work is proceeded with, we had again to consider two cases: case C, connecting the pumps directly to some of the turbines in the Power House. Case D, using all the power from the Power House to produce electric current, and then using part of the current to operate motor driven pumps.

The question of connecting the pumps direct to the water wheels was considered, but on account of the low available head and the resultant slow speed of the turbines, it was found advantageous to operate direct connected generators in the Power House, using the electric power so generated to operate motor driven pumps. This scheme not only simplifies the design of the pumping units and their connections, but provides a most flexible plant. For example, every turbine unit is available at all times, that it is possible to operate, for either furnishing power for pumping purposes, or any other electric power service required. In the case where the turbine is direct connected to the pump, then that turbine can be used for pumping purposes only.

As the Power House at times will not be in operation on account of Frazil, High Water, etc., and as there is a large difference between summer and winter power, it was also necessary to consider the case of providing an Auxiliary Steam Plant.

We, therefore, calculated the capital cost, cost of maintenance, and cost of operation of the following:

Canal and Tailrace.

Hydro-Electric Power House (Power House)

Auxiliary Steam Electric Plant.

Pump House, operated electrically.

Standby Steam Pumping Plant.

As will be seen, it was found cheaper to discard entirely the old steam pumping plant and built a new one, and finally it was found advantageous to discard this new Plant altogether, and enlarge the Auxiliary Steam Electric Plant for all requirements.

We first calculated the cost of the Canal and Tailrace as pro
(Scheme I) and the results of our studies, owing to uncertainty
the nature of the bottom of the Canal to resist scouring and the ten
of the retaining walls to slide, led us to calculate the cost of the max
possible development of power from the Canal with paved botto
maximum enlargement of the Tailrace (Scheme II).

FILTRATION WORKS, BRIDGES, BOULEVARDS, CONTRACTORS' CLAIMS.

Filtration Works.

The Filtration Works were built for a capacity of 50 million Imp
Gallons per day but are not yet in operation. The average daily quan
of water pumped last year was 54½ million Imperial gallons, run
for some periods of three hours, at a maximum rate of 73 million Imp
gallons. The Filtration Plant as built would, therefore, be insuffic
for the present requirements of the City and either it would have t
worked much above its normal capacity or a mixture of filtered
unfiltered water would have to be used. Both conditions are undesira
and such a situation should be avoided.

Bridges.

Under the present plans it is contemplated to build eleven brid
over the Tailrace and Canal, viz.:

Name	Location
1. Wellington	Tailrace
2. Buffalo	Tailrace
3. Filtration	Sta. 14.00
4. Church	Sta. 41.80
5. Woodland	Sta. 81.30
6. Location not decided.	
7. Asylum	Sta. 124.75
8. Crawford	Sta. 135.50
9. Knox	Sta. 190.10
10. Latour	Sta. 231.60
11. Lasalle	Sta. 269.39

The cost would be the same in all cases, except for Scheme II, when the Wellington and Buffalo Bridges would have to be longer owing to the widening of the Tailrace.

The Head gates of the Canal are a part of the Lasalle Bridge.

We have, therefore, left out the cost of 10 bridges in Schemes I, III, IV and V, but have included the cost of Lasalle Bridge in all Schemes. We have also added to Scheme II, the cost of the Wellington and Buffalo bridges. Rip-rapping at other bridges than Lasalle may possibly be needed for all Schemes, but its cost has been added only to Scheme II.

The rip-rapping we have figured upon, around the bridge piers in the Canal, extends down stream for 100 feet from the head of the piers and for the whole width of the Aqueduct. The bottom of the Canal, where it is in earth, is excavated for a depth of 6 feet or to rock, if the rock is less than 6 feet from the bottom of the Canal. Five feet in depth are filled up with large and small stones and clay puddle, over which is laid 1 foot of good concrete.

Boulevards

The cost of land for Boulevards has been included only in Schemes I and II. Owing to the grading of slopes in Schemes III, IV and V, part of the land needed for Boulevards is used for the banks, and the balance becoming useless has been omitted.

We cannot estimate in dollars and cents the value of the Boulevards. Whatever value the Boulevards may have to the City is beyond the scope of this Report.

It must, therefore, be understood that there is no land for Boulevards in Schemes III, IV and V and that in Schemes I and II, we have included the cost of land for Boulevards, and whatever grading and filling are included in Cook's Contract and nothing else.

Contractors' Claims.

These being the same for all five cases, have not been include

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Frazil

Messrs. Ernest Marceau and John Kennedy, in their Report, May 6th, 1907, addressed to Mr. Frank Dowd, Setretary of the Committee of the City of Montreal, say in their last paragraph:

"The details of the Works at the entrance of the Aqueduct an
"intake of the conduit are not yet fully worked out, but fron
"fact that the position of the present aqueduct intake is a
"favorable one, and that no trouble has ever been experie
"from frazil entering it, we are of the opinion that the works ca
"so designed and built, that their operation will not be seric
"interfered with by frazil."

Mr. F. Clifford Smith, in his official history "The Montreal W Works, 1913", page 35, quotes Messrs. J. H. Harrington and Thos Hickey, as follows:

"We have given considerable attention to the question of whet
"or not the frazil or slush ice would make any complications
"regards the entrance of the river water through submerged por
"protected by wooden slats or screens. A considerable numb
"of personal observations by Messrs. Janin and Lesage have be
"made by holding a screen in the water in this vicinity at tim
"when frazil is known to occur at other places. Available da
"indicate the comparative absence of complications as to fraz
"In recommending the construction of an intake 1200 feet fro
"shore, we beg to state that we have considered this matter wit
"respect to the purification of the supply. Taking everything int
"consideration, we are convinced, as above stated, that it will b
"wise to carry out Mr. Janin's recommendations for the outer
"intake."

The Ratepaying Engineers, in their Report of 1916, paragraph 7, say:

"Serious operating troubles, due to frazil and other ice are inevitable. "These will greatly reduce the maximum output below 7000 horse "power and may cause complete stoppage of the plant during a "more or less protracted period every winter."

These opinions are from high authorities who are better acquainted than we are with the conditions at the entrance of the aqueduct.

The Engineers who have studied and recommended the enlargement of the aqueduct have provided for a long extension of the cribwork at the entrance, to prevent the formation and admission of frazil.

We have omitted the cost of this cribwork, as it may be built after the works have been in operation and conditions studied.

It is certain that frazil and anchor ice will give trouble, and to the best of our knowledge there is no way to prevent same. We have, therefore, provided for an auxiliary steam plant to furnish power during times of ice trouble. For the purpose of estimating we have assumed that on the average there will be a decrease in hydraulic power equivalent to a complete shut down of 2.4 months each year.

Dredging

Any dredging required for Schemes I, II and III, at Outlet of Tailrace, has been provided for in our estimates.

CONSUMPTION OF WATER BY CITY

The average quantities per day of water pumped during t
1903–1913 are shown on the following table. The percentage of i
are also shown:—

YEAR	M.I.G.	PERC. OF INCREASE
1903	24.5	
1904	27.7	13.0% over 1903
1905	30.1	9.0% " 1904
1906	31.7	5.5% " 1905
1907	34.0	7.2% " 1906
1908	35.7	5.0% " 1907
1909	36.7	5.5% " 1908
1910	38.6	5.2% " 1909
1911	42.8	10.9% " 1910
1912	47.3	10.5% " 1911
1913	52.0	9.5% " 1912

In 1916 the average quantity of water pumped per day
54,625,462 Imperial gallons. The percentage of increase in the
consumption between 1903 and 1913 is 112%, and the percentage bet
1904 and 1913 is 88%.

Our calculations are based on an increase of 86% above the qua
of water pumped last year, and we have estimated that such an inc
will take place in from 5 to 10 years.

It is this increased quantity we have called the future needs of
City.

Power Actually Used for Pumping and Lighting.

Future Requirements for Pumping and Lighting.

From the information we have been able to obtain, we give, in t
following Table, the amount of power actually used for pumping a
lighting by the City and the adjacent municipalities of Outremo
Westmount, Maisonneuve and Verdun, including the power needed f
the filtration plant as now built.

Considering the rate of increase in the consumption of power which has taken place during the last ten years, we have also estimated the probable needs of the City and adjacent municipalities for the near future, say within the next five or ten years. This is also given in the statement below. It will be seen that the City and surrounding municipalities mentioned above, now use practically 20,000 H.P., for pumping and lighting, and that the requirements for the near future will not be less than 30,000 H.P.

POWER (H.P.)

DESCRIPTION	Power actually used by City, pumping 60 M. I.G. per day, and for lighting.			Power needed in near future, pumping 100 M. I.G. per day, and for lighting.		
	Pumping	Lighting	Totals	Pumping	Lighting	Totals
Pumping Atwater Ave.....	4,710			8,570		
Filtration " "	2,960			3,270		
TOTAL.....	7,670			11,840		
Electric Pumps.....	2,000			2,500		
TOTAL FOR WATER SUPPLY.....	9,670			14,340		
Sewers.....	520			520		
TOTAL PUMPING FOR CITY OF MONTREAL	10,190			14,860		
Lighting City.....		2,890			4,330	
TOTAL PUMPING AND LIGHTING.....			13,080			19,190
Montreal W. & P. Co. system.....	5,600			8,960		
Outremont, Westmount, Maisonneuve, Verdun.....		1,064			1,600	
TOTAL FOR PUMPING CITY AND M. W. & P. CO. SYSTEMS.....	15,790		15,790	23,820		23,820
TOTAL FOR LIGHTING..		3,954	3,954		5,930	5,930
TOTAL HORSE POWER..			19,744 say 20,000 H.P.			29,750 say 30,000 H.P.

DEFINITION OF THE TERM "HORSE-POWER"

To avoid misconception of the term "Horse Power" in our Report the letters H.P. represent the horse power or energy due to falling wate without any losses.

As this water passes through turbines and puts machinery in motion to be transformed into Electrical energy and sent over Distribution lines to do useful work, some of the original energy is lost step by step, and all our calculations are based on the following table of efficiencies in horse power for pumping and lighting.

The electrical horse power available at the Power House, or delivered according to present contract at 2200 volts, will be indicated by E. H. P., and for the power delivered at other places, the name of the place will precede the letters H.P. and E.H.P.

EFFICIENCIES IN PERCENTAGES OF THE WATER HORSE-POWER

Lighting

ITEM	EFFICIENCY		OVERALL EFFICIENCY	
Power at Fall	100%		100%	
Turbine	82%		82%	
Generator	93%		76.26%	
Outgoing Lines	98%		74.73%	say 75%
Lines to Central Distributing Sta	91%		68%	
Rectifier	92%		62.6%	say 62%
Line	96.8%		60.6%	" 60%
Switchboard P. House to Lamp	60.6%	=	81%	
	74.73%			
" Main Distributing Station Lamp	60.6%	=	89%	
	68%			

Pumping

Low Level Pumping Atwater Avenue

Power House Switchboard	75%		
Motors	90%		67.5%
Pumps	80%		54%
Filtration Plant Efficiency Transformer and Line	96% x 75%		72%

High Level Pump Efficiency, McTavish Reservoir Smaller Units

Motor and Pump	68.8%	say	69%
Eff. at Switchboard	68%		47%

Papineau Avenue Pump Efficiency

Motor and Pumps	64.4%		
Eff. at Switchboard	68%	say	44%

From this Table it follows that:

TO PRODUCE:	REQUIRES:	
1 E.H.P.	1⅛ H.P.	
1 lamp H.P., 746 Watts	1⅜ "	
1 pump H.P. at Atwater Avenue	1.85 "	or 1.39 E.H.P.
1 pump H.P. at McTavish Reservoir	2.13 "	" 1.60 "
1 pump H.P. at Papineau Avenue	2.28 "	" 1.71 "

Efficiencies differ according to the machinery employed to transform the energy of falling water, and the above table is given only to show the value of efficiencies which we have used in our calculations.

PROJECT AS DESIGNED — HYDRAULIC DATA — REVIEW AND COMMENTS ON SAME — REASONABLE EXPECTATIONS OF DEVELOPMENT IN HORSE-POWER.

We are indebted to the Chief Engineer of the City and his Staff for copies of all documents and hydraulic data bearing on the Montreal aqueduct.

These studies are exceedingly well made and have been found to be correct in agreement with assumptions made.

We cannot consider, however, as permissible, the high velocities assumed for the Headrace, and we differ somewhat as to the co-efficient for retardation of flow due to the character of the Canal bottom, factors which affect the quantity of power to be derived from the development.

In the information given it is stated that the flow in the Canal has been obtained by means of the Kutter formula assuming a slope of 3.3 in 27,000 feet, and a value of 0.02 for the co-efficient "n" (earthen channel in good order). The same co-efficient of 0.02 has evidently been assumed for the upper surface of the water when covered with surface ice.

The Ratepaying Engineers, we are informed, assumed a high co-efficient of roughness for their calculations of flow, and adopted value of n = 0.03 as more correct in their opinion to meet the condition of the Canal, particularly that section which is in the rock cut, th effect being to give somewhat lower values in flow capacity.

After having given consideration to all the conditions affecting thi factor, and examined the bottom and sides of the Canal, we have com to the conclusion that co-efficient n = 0.025 is best suited to the condition of the Canal.

The Canal is assumed to be covered with two feet of ice for winte conditions. It is also assumed that the hydraulic gradient is paralle to the bed of the Canal, making the depth of water uniform; in othe words, the difference in level or friction head between the entrance o the Canal and the Forebay, viz: 3.3 feet, is totally absorbed in cases o maximum flow to produce motion or induce the water to flow in the Canal.

When the turbines, however, take only a percentage of the natural flow, then only a percentage of the total friction head is absorbed.

Probably one of the most critical questions to be considered, which affects mostly, in this case, the amount of energy to be obtained from the development, is the question of permissible velocities as governed by the character of the bottom and sides in both the Headrace and Tailrace.

We are informed that the Tailrace will be paved, thus permitting of velocities as high as 8 or 10 feet per second = (5.46 to 6.82 miles per hour).

The bed of the Headrace, for a large proportion of its length, is of such a character as will permit only of a very low flow velocity, in order to prevent scour and danger to the walls. On this account we have looked with particular care into the question of limiting velocities for the project as designed.

Velocities:

The principal elements of a water power development are, the sectional area of the Power Canal, the permissible velocity of flow due to the material through which the Canal is built so as to prevent all danger of scouring, the amount of water available and the net head.

For the project under execution we may say that the supply of water is practically unlimited. The section of the Headrace or Canal may be said to be fixed, that is, it cannot be further enlarged without great and unreasonable cost, on account of the large percentage of the side-walls already built, and it must remain the governing factor as to amount of water available to produce power, assuming an adequate enlargement of the Tailrace where no work has yet been done.

The capacity of the Canal is, in turn, necessarily dependent on the maximum velocity which can be permitted on the earth bottom sections of the Canal, side concrete walls being provided under existing contracts.

We have given the most serious consideration to this question, and comparative studies have been made to determine the resulting flow and power, considering the nature of the material forming the bottom of the present Canal, and also a concrete paved bottom.

Taking first the case of development under the present plans, we find the following reference to the nature of the material, in the Report dated February 21st, 1914, of Messrs. J. A. Jamieson, R. S. Lea, and G. R. Heckle, on the Montreal Water Supply Conduit:

"The soil through which the aqueduct is being excavated, and
"in which the conduit is embedded for the greater part of its length
"is largely composed of boulder clay or rock powder. When
"comparatively dry or well drained, it will stand in a bank with
"practically vertical face, but when fully saturated with water
"tends to flow in a horizontal surface and is easily eroded and
"transported by running water. This latter property has a very
"direct bearing on the safety of the conduit, in view of the proximity
"of the aqueduct excavation."

The Ratepaying Engineers in a memorandum submitted to this Board, under date of March 5th, 1917, referring to the Canal Section of the Aqueduct, say:

"Maximum permissible mean velocity, with material as found in
"earth section, shall not exceed 2.5 feet per second."

In a Report made during 1894, Messrs. Keefer and Vanier, speaking of the Tailrace, say:

"The surface inclination of the water when delivering its full
"economical discharge with a velocity of 100 feet per minute, or a
"little over one mile per hour, will not be more than one-half that
"of the present aqueduct."

This is equivalent to a velocity of 1.65 feet per second (probably surface velocity) and would indicate that the surface velocity in the old aqueduct was as high as 3.33 feet per second (2.27 miles per hour), equivalent to a mean velocity of about 2.7 feet per second (1.84 miles per hour).

On the other hand, Mr. T. C. Keefer, in a Report to the City of Montreal, dated December 1886, gives the result of a few measurements of surface velocities made in August 1884, which gives an average surface velocity of 1.70 feet per second (1.25 miles per hour) equivalent to a mean velocity of about 1.3 feet per second (0.89 miles per hour).

No accurate information is available as to whether erosion occurred at any time in the old aqueduct canal.

From the specifications for Contract No. 2, it would appear that it was anticipated that exceedingly soft material was likely to be encountered in some sections of the work, as paragraph 46 reads as follows:—

> "In any case, where in the opinion of the Engineer, exceedingly "bad plastic or aqueous material is encountered in the bottom "excavations of the Canal, particularly between Stations 45 and "90, and whenever this material (soft clay pockets, quick sand, "loam, leaf mold or muck, etc.) is so soft or silty as to be improper "to insure the required bearing power of the soil, the Contractor "shall be required to furnish and drive wooden piles to carry the "footings....."

Some of the best authorities on hydraulics give figures for the allowable velocities of water in earth canals, for different materials, which vary between the following values:

	Safe bottom velocity in feet per second.	Safe bottom velocity in miles per hour.	Mean velocity in feet per second.	Mean velocity in miles per hour.
Soft earth.....	0.25 to 0.50	0.17 to 0.34	0.33 to 0.65	0.23 to 0.44
Clay.....	0.25 " 0.50	0.18 " 0.34	0.33 " 0.65	0.23 " 0.44
Sand.....	0.4 " 1.00	0.27 " 0.68	0.6 " 1.3	0.41 " 0.89
Gravel.....	2.0 " 2.6	1.33 " 1.77	2.62 " 3.0	1.78 " 2.03
Broken Stone.....	3.3 " 4.3	2.25 " 2.93	4.0 " 5.5	2.73 " 3.75

No paving is shown on the plans for the Tailrace proper, where high velocities are bound to develop on account of its small section and steep grade. Chief Engineer Mercier, in his Report of the 16th December 1916, recognizes fully the necessity of lining with concrete that section of the aqueduct, and states that it is the intention to provide for same.

We fully endorse Mr. Mercier's decision in this.

In view of the description of the material given by the Board of Investigation for the Conduit, and other information as mentioned above, and after having inspected the works, we have concluded that for the first scheme to be considered, that of the work as per present plans, we could not assume a higher permissible mean velocity for the earth sections of the Headrace than 1.5 feet per second.

In our studies, under the Heading of Scheme I, we assume that the bottom is safe for a mean velocity of 1.5 feet per second (1.02 miles per hour), but we cannot, however, accept or recommend this, or any other velocity, until thorough tests have been made to ascertain what velocity it will be safe to assume in order to guard against scouring of the bed and against the undermining of the side-retaining walls.

ABANDONING POWER DEVELOPMENT

Schemes IV and V

In this case there is no land available for Boulevards and the aqueduct is used only to bring water to the Pump House at Atwater Avenue.

We have, however, included the cost of finishing the South Wall to the Rock Cut to correspond to the North Wall ($43,300.00) to allow of the completion of the aqueduct at some future time, if it is ever deemed advantageous.

We have also included an arbitrary amount of $279,575, being 15% of the cost of the uncompleted part of the contract; this amount may be increased or decreased in the final settlement with the Contractor.

We have included, as we have done in all cases, the interest until the completion of the work, although the City is not allowed to charge interest to Capital Account.

In this case it amounts to $1,072,948.00.

We have estimated the cost of abandoning the work at: $5,895,000.00.

Scheme I

Present City Scheme, but with mean velocity in Headrace limited to 1.5 feet per second.

From the preceding considerations in studying the power obtainable, as based on the present plans, under winter and summer conditions, leaving out the question of frasil, we have assumed the mean velocity at 1.5 feet per second (1.02 miles per hour), in the Headrace, on account of the nature of the earth bottom.

As it is intended to provide a substantial paving for the bottom of the Tailrace, a velocity of 8 feet per second (5½ miles per hour) will not be excessive, and we have adopted this figure as the maximum mean velocity in the Tailrace.

It is assumed that in winter there will be an ice covering of two feet in the Headrace, though it is possible that during excessively cold winters, a slightly greater thickness of ice may form.

In the Tailrace, on account of velocities being higher than 3.5 feet per second (2.4 miles per hour) there will be no ice covering in winter.

This power has been calculated for normal conditions, winter and summer respectively. Floods and frasil will cause unfavorable conditions from time to time, probably every year, either on account of loss of head or decreased flow, and it is to be distinctly understood, that at such times, the power stated will be considerably reduced. The only

remedy against floods and frazil troubles is an auxiliary steam plant which must form a necessary adjunct to the water power scheme under consideration.

We find that for the limiting velocity of 1.5 feet per second (1.02 miles per hour) in the Headrace, and under other conditions mentioned above, the power available, as based on the lowest winter month, and the lowest summer month average gauge readings respectively, at both Entrance and Outlet gauges, is as follows:—

Winter..... 7,445 H.P. = 5,600 E.H.P.

Summer.....11,900 H.P. = 8,900 E.H.P.

The Headrace is the controlling factor in both cases, that is, the Tailrace, as designed and paved all through, is large enough to pass all the flow of the Headrace, with velocities well under the limit of 8 feet per second as fixed. In fact, the highest velocity produced in the Tailrace under this scheme will not be over 6.2 feet per second.

We have assumed that the summer power of 11,900 H.P. will be available for 7 months, so that during the 5 winter months the power of 7,445 H.P. will be available say for 2.6 months, and that there will be no water power available for the balance of the 2.4 winter months, pumping during the periods of deficiencies being done by the auxiliary steam plant.

We have shown before that the City will, in the near future, need to pump a daily average of 100 million Imperial gallons of water for domestic supply.

The power required for pumping this quantity of water will be 8570 H.P.

In this scheme there is no paving provided for the Headrace and as paving will certainly be required in a good many places, the velocity could then be increased. If this were done, Scheme I would practically become Scheme II.

The Filtration Plant at its present capacity of 50,000,000 Imperial gallons per day when placed in operation will require 2960 H.P. for pumping and for electric heating, as at present installed. When it is increased to a daily capacity of 100 million gallons, the power required for both pumping and heating will be 3270 horse power. The Filtration plant could be heated by exhaust steam from the auxiliary plant at a greatly reduced cost, as compared with electrical heating.

With this change in the heating system the Filtration Plant will require 1910 H.P. for pumping when the capacity is increased to 100 million gallons per day.

The plant, under Scheme I must then produce power as follows:—

Needed for pumping 100 M.I.G. per day	8570 H.P.
Needed for Elec. Current for filtration per day	1910 "
TOTAL	10,480

During the summer period, say for 7 months, the water power development will take care alone of the above requirements. During the winter period the development will require the help of a steam auxiliary, and our estimate for the scheme to meet all conditions is given below.

	TOTAL COST	OPERATION
Actual Needs	$8,537,000	$590,000
Future Needs	$9,177,000	$679,000

The amounts charged for Interest are:

in the first case	$1,200,744
in the second case	$1,231,234

This project includes the cost of land for Boulevards and the cost of the Lasalle Bridge.

Scheme II

Winter power: 13,000 H.P.

Summer power: 24,500 H.P.

In Scheme II, we have considered possible improvements to the present scheme, and have studied the conditions which will give a maximum practical hydraulic development for the City.

This Scheme is based on the following assumptions and alterations to the present scheme.

The Headrace remains the same, excepting that the earth sections are paved with concrete and the sides of the rock cut below the gravity walls given a straight and smooth concrete facing instead of the irregular concrete finish called for by the specifications.

The paving we have considered is the same as specified in paragraph 38, page 8 of the specifications for Contract No. 2.

The surface ice in winter is assumed to be 2 feet thick.

The Tailrace is radically changed. It is widened from 113.85 feet to 172 feet; the bottom is paved with concrete one foot thick, and the grade altered from 4 feet to 2.5 feet in 2,900 feet, the bottom at the outlet remaining at elevation 2.00 above datum.

Under these conditions we estimate that the Scheme is capable of the following power development.

WINTER — 13,000 H.P.

This power is subject to decrease or interruption on account of frasil or anchor ice. It is based on the lowest average winter month for 19 years (1895 to 1914); velocity in Headrace 2.82 feet per second.

SUMMER — 24,500 H.P.

Based on the lowest average summer month in two years, which is the only period of time for which we have any gauge records. The maximum mean velocity in Headrace is limited to 3.25 feet per second.

The velocity in Tailrace is limited to 8 feet per second.

We have estimated for a development of 13,000 H.P. winter and summer, which will be used as follows:—

Needed for pumping 100 M.I.G. per day	8570 H.P.
" Electric Current for filtration per day	1910 "
	10,480 "
Excess power	2,520 "
Total	13,000 "

As in the case of Scheme I, this hydraulic development must be supplemented by an auxiliary steam plant to provide power during times of ice and frazil troubles.

It is also assumed that the 13,000 H.P. above mentioned will be available for seven summer months. During the five winter months we have assumed that on the average there will be a decrease of 2.4 months each year; during that time power will have to be furnished by the auxiliary steam plant.

Additional power over the 13,000 H.P. may be produced during the summer only, at a cost of $5.06 per H.P. or $6.74 per E.H.P. *It has no market value.*

We have not taken it into account in our calculations, except by providing foundations for a future extension to the power house, should it be decided later to utilise this additional summer power.

13,000 H.P. will pump a yearly average of 124,000,000 gallons per day, but in that case the summer average will be 142,000,000 gallons per day, and the auxiliary steam plant shall have to be used during the summer.

If instead of developing 13,000 H.P., 2,000 H.P. are developed in addition, out of the additional 11,500 H.P., then the summer average of 142,000,000 can be pumped by Hydraulic Power and the cost of operation on the H.P. basis will be reduced from $56.90 to $50.35.

Part of the balance of 9,500 H.P. may also be used to pump large quantities of water during the summer only, to provide water for fountains, parks, etc., and to clean the streets. This water can be pumped at a cost of $3.20 per million gallons.

Another part of the balance might also be used for refrigeration of cold storage warehouses or to manufacture cheap ice.

We have estimated from accurate data that the capital cost required for an ice manufacturing plant of a capacity of 300 tons per day, during seven months, if located at Atwater Avenue, would be $337,000.00.

This amount might be diminished by about $60,000.00, if the buildings of the present pump house (which would then have been moved near the filters) were used for the ice plant and as a garage for the motor trucks used in its transportation.

This plant would manufacture ice from filtered water, at a cost of 54c per ton.

We have estimated that the cost of delivery at different central places, such as the bath houses of the City, would be about 45c per ton, so that the cost of ice delivered (not distributed) would be about $1.00 per ton.

One ton would provide 100 blocks of 20 lbs. of ice at a cost of 1c per block.

We have calculated the cost of developing 13,000 H.P. summer and winter, as follows:—

TOTAL COST	COST OF OPERATION
$10,609,000.	$740,000.
Amount charged for interest	$1,299,398.

Scheme III

Summer Power	9500 H.P.
Winter Power	5000 H.P.

Scheme No. 3 provides for enlarging the Headrace with sloping banks without Boulevards; the Tailrace is the same as provided for in Scheme I.

We limit the mean velocity in the Headrace to 1.5 ft. per second. Two feet of surface ice will form in winter.

The lowest average summer month in two years is November 1908 when the power produced would have been 9500 H.P. The Headrace is the controlling factor and the velocity in the Tailrace is 4.1 ft. per second.

The lowest winter month is March 1912 when the power produced would have been 5000 H.P. with Headrace as controlling factor.

That part of the Headrace situated in the rock section, 6,000 ft. in length, will be practically as shown on present plans, except that on the South side, the bank will be sloping above the ledge instead of being supported by gravity walls as on the North side where they are built.

In the East earth section for a length of 14,000 ft. the banks slope 2 to 1.

Between Stations 140 and 128 the width at bottom will be 130 ft.

Between Stations 128 and 44 the width at the bottom will be 91 ft. This section will govern.

Between Stations 44 and 0, the width at the bottom will be 122 ft.

We have estimated the cost of Scheme III, as follows:—

	ACTUAL NEEDS	FUTURE NEEDS
Total Cost	$7,515,000	$8,205,000
Cost of Operation	504,000	648,000
Interest charged	1,152,076	1,184,924

In this Scheme there is no land for Boulevards, the walls are built only in the Western earth section, and the Tailrace is built only large enough for the production of 9500 H.P. It could be increased in capacity at some future time, as per Scheme No. 2, but in that case the Tailrace would have to be enlarged and the walls demolished, and new bridges required for Wellington and Buffalo.

Scheme IV

COST OF PUMPING BY STEAM

In this Scheme there are no Boulevards.

To Pump 100 million Imperial gallons per day we calculated, first, the cost of adding two new DeLaval Pumps and new boilers to the existing plant.

The existing plant has been lately valued by Supt. Lesage at $674,000.00.

With additions, its total value would be $1,032,696. and the cost of operation $494,924 per annum.

We have also estimated the cost of an entirely new plant consisting of 6 DeLaval units of the same capacity with new boilers, buildings, etc.

The capital cost is $709,240.00, and the operating cost is $369,744.00 per annum.

There is, therefore, a difference in favor of the new plant of $125,180.00 per annum, and even if we add 5% of $674,000.00 to cover the dead loss of the old plant, the difference will still be $91,480.00 per annum in favor of a new plant.

This difference would, in reality, be much larger owing to the necessity of remodelling the old plant, and to the difficulty of supplying water to the City during the remodelling.

When the work is completed it is planned to have the water flow by gravity from the filtration plant to the steam pumps increasing the suctions by about 12 feet. If the steam plant is not to be altogether discarded it will have to be remodelled to suit the new conditions and considerable piping shall have to be done.

The best location for the steam pumps would be near the Filtration Plant, as that plant could be heated by exhaust steam instead of electricity as it is now.

The current used for heating by electricity is paid by Tariff I of the City. When the addition to the new plant is made (and this should be done at once) the cost of heating would be at actual rates, at least $25,000

per annum. This amount would be saved each year by using exhaust steam.

Large quantities of steam will be available for heating, if required, at no extra cost.

We have estimated the cost of pumping by steam as follows:—

	CAPITAL COST	COST OF PRODUCTION	INTEREST CHARGE
Actual Needs.....	$6,434,000	$546,000	$1,098,590
Future Needs.....	$6,703,000	$712,000	$1,111,411

The plant we have estimated on, which employs DeLaval Pumps, hand-fired boilers and cheap fuel, as designed by Supt. Lesage, gives excellent results, but the cost of labor, which is, in this case, an important item, might be diminished by the use of mechanical stokers. In that case we have estimated the saving at $24,000.00 per annum, and the increase in capital cost at $56,000.00.

As the saving would be the same for all Schemes, except Scheme V, we have left it out of our calculations.

COST OF PUMPING BY ELECTRICITY

Scheme V

In this case we have used for the cost of electric current the rate of $30.00 per E.H.P. according to the present contract with the Montreal Light, Heat & Power Company.

At the request of Mr. Commissioner E. W. Villeneuve we wrote to the Companies supplying electric power in Montreal, and enclosed Mr. Villeneuve's letter, asking at what rate the Companies would be prepared to supply the City with power per day of 24 hours, for a period of 25 years.

We received two letters from the Montreal Light, Heat & Power Company, advising they would be prepared to undertake the street lighting of Montreal, at the present prices, for a period of 40 years from date, and also quoting tentatively for 3 phase alternating current 11,000 volts, delivered at the City Pumping Plant, Atwater Avenue, $25 per annum per H.P. (probably E.H.P.) of maximum demand, on the basis of a 20 year contract, and $24.50 per annum per H.P. (probably E.H.P.) of a maximum demand on the basis of a 40 year contract. This for 24 hours' service.

The current which is now furnished to the City for 24 hours' service is of two kinds:

1. A current of 2200 volts in units of 400 E.H.P. or more, at a cost of $30.00 per annum.

2. A current of 2200 volts in units of from 100 to 399 E.H.P. at $35 per annum.

Current at 11,000 volts would have to be stepped down for use, and to the price of $25.00 would be added the operation cost of transformation, and electric losses.

The average pumpage at Atwater Avenue is at the rate of 54,000,000 Imperial gallons per day. On account of the insufficient reservoir capacity, the output varies from 73,000,000 maximum to 45,000,000 minimum. This variation greatly increases the cost of power for operating.

When the City buys power from a Company for pumping, the Company must be ready to deliver it for the peak load at any time, and very properly charges for the said peak load all year long at $30.00 per E.H.P. For instance, at the McTavish pump a test was made, showing that the pump working at full capacity for two hours was pumping at the rate of 5,760,000 gallons per day, and used 523.5 E.H.P. The City paid $15,660 for power used at McTavish Street, in 1915, or for 522 E.H.P. at the rate of $30.00 per annum. During that year the average daily pumping was 4,620,000 gallons, which requires about 420 E.H.P. The

cost of this average power is, therefore, $37.35 per E.H.P. or an increase of about 25%.

At Papineau Avenue, where the nominal rate is $20.00 per E.H.P. per annum, the cost of power actually used was $27.72, or an increase of 38%, the difference between the percentages of increase being due to the respective efficiencies of the pumps.

In the absence of complete details, of the terms on which electric power would be supplied, for this service, we have based our estimates on the following:—

First:—buying power at $30 per E.H.P. maximum demand.

Second:—buying power at $25 per E.H.P. maximum demand.

(as per terms of present contract).

SCHEME V. at	TOTAL COST		COST OF OPERATION	
	Actual	Future	Actual	Future
$30 per H.P.	$6,102,000	$6,268,000	$565,000	$712,000
$25 "	6,102,000	6,268,000	529,000	656,000

The amounts charged for interest are:

Actual	Future
$1,082,524	$1,090,191

It is recommended that at least two power transmission lines be installed to the pump house in case of purchase of power. The present steam plant, and its emergency intake, is a further insurance against any serious interruption of your service.

We must point out that the maximum pumping occurs only during four months of summer, during which time the Companies have an excess of power, whereas in winter the maximum is very seldom above the average for the whole year, and it could easily be arranged never to exceed it. The Power Companies might possibly be ready to grant better

terms to the City if the facts were better understood.

ELECTRIC LIGHTING

We have seen that in case the Filtration Plant is heated by exhaust steam, the power needed in the near future by the City, will be as follows:

Pumping at Atwater Avenue	8,570	
Filtration Plant	1,910	10,480
Lighting		4,330
		14,810 H.P.

None of the Schemes we have considered gives enough power for lighting. The only question before us, therefore, was to find out whether it would be cheaper for the City to buy power and do its own lighting, or have the lighting done by contract, as at present.

We have estimated for the near future on 3,000 lamps of 6.6 amperes, and 2,000 lamps of 4 amperes, as per Mr. Parent's Report to you, dated September 12th, 1916, assuming wires underground for a distance of 25 miles of streets, and aerial distribution for 425 miles of streets.

We estimated that for the City to do its own lighting would require a capital cost of $1,670,000 and the cost of operation, not including the cost of current, would be $286,000 per annum, and that the cost of lighting by contract at present prices would be $365,000 per annum. This would leave a difference available for current of $79,000 per annum, or $18.24 per H.P. or $24.32 per E.H.P. at Atwater Avenue.

We must remark, however, that the price of current is a small item of the cost of lighting, but that the place where the current is delivered has great importance on this item, so that if the current could be bought by the City at $25 per E.H.P. delivered at sub-stations, the cost of doing the lighting and buying current, and the cost of having the lighting

done by contract would be equal.

It must be noted that should the City take over the lighting it will no doubt have to erect some 18,000 extra poles. This should be guarded against, and it is suggested that all the aerial systems be placed under the control of the Commission now in charge of the underground work. There is no doubt that in that case the cost of lighting would be materially lessened.

We have seen that:

Scheme II, has 2,520 H.P. available, and that there will be 25 miles of street with wires underground.

The City pays for the lamp posts, the cables laid in place, and pays also the rent of the conduits where the cables are laid.

When the price of copper has become normal the City might undertake that part of its lighting.

For the time being it would be more advantageous for the City to continue to have the lighting done by contract, as at present, leaving the consideration for doing its own lighting for some future time, in case it could produce electric current at a lower price than it could be bought, and when the price of copper would have become normal again.

TOTAL COST AND COST OF OPERATION FOR ALL SCHEMES. (Power given in H.P.)

	Potential Hydraulic Power		Power development.			TOTAL COST		COST OF OPERATION	
			Pumping and Electric Power		Heating				
	Summer	Winter	Summer	Winter	Winter	Actual	Future	Actual	Future
SCHEMES:									
I. Present Plant.....	11,900	7,445	10,500	10,500	Heating by Exhaust Steam.	$8,537,000	$9,177,000	$300,000	$679,000
II. Maximum power available.....	24,500	13,000	13,000	13,000			10,609,000		740,000
III. Minimum power available.....	9,500	5,000	10,500	10,500		7,515,000	8,205,000	504,000	648,000
IV. Pumping by Steam...	Nil	Nil	10,500	10,500		6,434,000	6,703,000	546,000	712,000
V. Buying Electric Current:									
$30 per H.P.....	"	"	10,500	10,500	1,400	6,102,000	6,268,000	565,000	712,000
$25 " "	"	"	10,500	10,500	1,400	6,102,000	6,268,000	529,000	656,000

NOTE: SEE "CONCLUSIONS" PARAGRAPH 5.

FINANCIAL STATEMENT

Loans authorized: Issued	$6,701,000.	
To be issued	3,799,000.	
Estimated discount		$10,500,000.00
		$ 319,000.00
Less Filtration Works	$1,894,480.37	$10,181,000.00
Less Pumps	72,137.99	
Amounts available for Aqueduct		1,966,618.36
Amortized at end of 1916		$8,214,371.64
		$ 274,008.25

Interest Charges

	ACTUAL NEEDS	FUTURE NEEDS
Work abandoned	$1,072,948	$1,072,948
SCHEMES: I	1,200,744	1,231,234
II	.....	1,299,308
III	1,152,076	1,184,924
IV	1,098,500	1,111,411
V	1,082,524	1,090,191

The amount of interest for each Scheme shown in the above Table, must be deducted from the total cost of each Scheme, as the City is not allowed to charge Interest to Capital Account, but must charge it to Current Expenditure.

The amounts chargeable to Capital Account are therefore:—

Work abandoned	$4,821,893	$4,821,893
SCHEMES: I. Present Scheme	7,335,880	7,945,675
II	.....	9,308,752
III	6,341,728	7,019,290
VI	5,334,723	5,591,137
V	5,019,150	5,177,077

Yearly Expenditure and Revenue of the Aqueduct

Year	Cost of Operation and Maintenance	Ordinary Revenue
1904	$ 200,772.27	$ 833,537.79
1905	226,990.42	911,520.13
1906	237,939.80	972,586.44
1907	291,942.03	1,027,179.67
1908	288,178.60	941,611.11
1909	272,496.22	984,432.60
1910	391,676.70	1,051,047.64
1911	454,897.12	1,168,209.01
1912	663,769.40	1,328,029.65
1913	811,464.39	1,626,147.31
1914	1,036,375.57	1,414,192.63
1915	1,195,309.55	1,374,743.14

The cost of operation, maintenance, etc., does not include the interest on the invested capital nor any provision for amortizing or depreciation.

NOTE: SEE "CONCLUSIONS" PARAGRAPH 5.

REMARKS ON COSTS AND CONCLUSIONS

It must be clearly understood that we have estimated the cost of the different Schemes on condition that they be executed with despatch, in a businesslike way, and without undue delays.

We have found that the cost of putting the canal in proper shape if the work were discontinued, is $5,894,846 of which $1,072,948 represents interest. We had, therefore, to charge $294,742.30 being the interest at 5% per annum on the said cost, to the cost of pumping by steam or of buying electric current (Schemes IV and V).

On account of fluctuating rates and prices, it is impossible at present to make an estimate of cost which would hold good for any length of time. This must not be forgotten in comparing estimates made as early as 1905 with those made now.

The estimates referred to at the beginning of our Report show a close agreement with our own, although calculated for different assumptions of the quantity of power obtainable from the Canal, and for different methods of utilising said power.

Our estimates do not include the cost of the filtration plant already built, nor of its proposed additions and operation, but include the cost of the power needed, and the cost of heating. We have not included either the cost of the main suction and discharge pipes beyond the Pump House; the cost of some of the bridges (as explained before) nor of the claims of the Cook Company.

These costs would be the same for all schemes.

As for Boulevards, which are provided for only in Schemes I and II, we have included the cost of land, fences and ditches, and whatever grading must be done by the Contractor, and nothing else.

In this Report five schemes are considered. The figures used are taken from works lately executed, with a percentage added to cover normal increase in cost of labor and materials.

The Tables all indicate "Present Needs" and "Future Needs". We would direct your attention to the figures for "Future Needs" only, as such will be justified by the time the plant is ready for operation.

COST OF SCHEMES

H.P. BASIS

	TOTAL COST	CAPITAL COST	COST OF OPERATION
SCHEMES: I	$874	$756.66	$64.66
II	816	716.06	56.90
III	782	668.50	61.71
IV	639	522.48	67.81
El. current at $30	597	493.05	67.81
V			
El. current at $25	597	493.05	62.47
Work abandoned	$562	$459.22	$28.07

We will now consider the schemes as described.

SCHEME I

Present Scheme

This scheme is the one to which exception has been taken, and we agree that it should not be proceeded with as outlined. It could not have developed the expected power.

SCHEME II

Maximum Hydraulic Development

This scheme shows the cheapest cost of operation per H.P. It is described at length in the body of the Report and considered in our Recommendations.

SCHEME III

Minimum Hydraulic Development

This scheme is inferior to Scheme II and need not be considered. It gives less hydraulic power and the auxiliary steam plant being worked to a much larger extent, the possible increases in the price of coal will affect the cost of operation to a greater degree.

SCHEME IV

Pumping by Steam

This Scheme considers finishing the Aqueduct simply as a channel to carry water to the Pumps, which are operated directly by steam. The high cost of operation is due to the charges against it of money already spent on the Aqueduct extensions. Had the old aqueduct been left as it was, simply as a supply to the steam pumps, a steam pumping plant would have been a most attractive proposition.

SCHEME V

Buying Power

There are two subdivisions to this Scheme, figured on electric power supplied at $30 and $25 per E.H.P. on the same basis as power is now purchased for pumping purposes.

Here as in the case of Scheme IV, the cost of operation is charged with the amount already spent on the Aqueduct extensions. To this is added such expenditure as may be required to put the channel in condition to carry the water supply to the pumps. This scheme is again referred to in our Recommendations.

From our examination we consider that it will be necessary to pave certain sections of the bottom between the walls, as a precaution against their sliding or turning over, due to the unstable nature of the ground. We have provided for such paving in our estimates.

Power for Lighting

There is not sufficient hydro-electric power in sight at present to justify your considering the taking over of the city lighting. This question has been treated at length in the body of the Report.

Filters

The Filters, as designed and now nearing completion, have a rated capacity of 50,000,000 Imperial gallons per day. We understand that plans are under way for a further extension to 100,000,000 Imperial gallons per day output, with possible future extension to 150,000,000 Imperial gallons. The present records show a maximum pumpage of over 70,000,000 Imperial gallons; this means that the filters have not sufficient capacity to meet the present demand.

RECOMMENDATIONS

Under ordinary conditions and with the figures now before us, we would have no hesitation in recommending the adoption of Scheme II with provision for Boulevards, as its cost of operation per H.P. per year is the lowest. But under the circumstances which have allowed of the Contractor being able to proffer a claim of $1,469,338.17 on a contract of $3,012,562 on which work to the amount of $1,148,731.48 had been completed at the end of 1916, the question is different.

We must also take into account the fact that the Contractor has to be reckoned with for any changes or additions to the present plan.

WE WOULD, THEREFORE, RECOMMEND:

1st. That the south wall of the Aqueduct be at once extended to the rock section and that the west earth section be completed with paving where needed, as this should be done for all schemes.

2nd. That no work be done on the rock section nor on the east earth section until the final scheme is decided upon. This also applies to the Tailrace.

3rd. That you immediately ask the several companies furnishing electric power in the City, for firm bids on power. Carefully worked out specifications should be furnished to the Power Companies setting forth the exact conditions of the service required.

Prices should be, at the same time, obtained from the Contractor for all changes and additions to the present contract.

As soon as this is done (and it should be done in a couple of weeks) you shall be able to come to a decision with full knowledge of the costs of operation of all schemes.

As all our figures will be in the hands of your Chief Engineer, he will be able to place before you the exact cost of each scheme.

In the meantime, studies should be started and designs made for the proposed electric motor driven pumping station. This station should be designed to pump the output of the proposed new filter plant, which is to be 100,000,000 Imperial gallons per day. Provision should also be made for future extensions. The equipment of this station will be the same whether you generate your own electric power, or buy it. The plans for the steam standby station should also be put in hand. We have suggested that the new pumping plant be located on the south side of the Aqueduct near the filters. This should provide a most convenient location for all piping connections. It also facilitates the connection of the steam standby to the heating system that is proposed for the filters.

No addition or alterations to the present steam pumping plant should be made.

The plans for the hydro-electric station may be delayed until you have come to a decision regarding the source of power.

WE WOULD ALSO RECOMMEND:

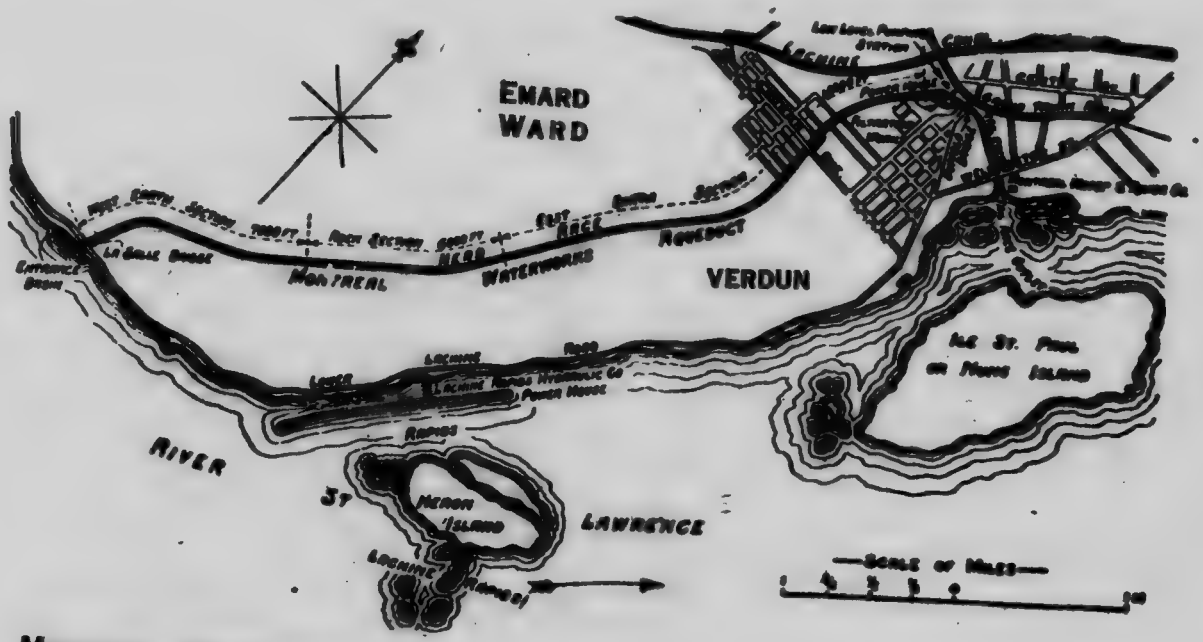
4th. That the lands required be secured at once, so as to prevent further delays to the work.

5th. That the addition to the Filtration Works at a cost of $900,000.00, as estimated on page 85 in the Annual Report of 1915, be proceeded with.

(SIGNED) H. E. VAUTELET,
Chairman.
" A. ST-LAURENT,
" JOHN B. McRAE.

H.E.V./McL.

MONTREAL, APRIL 30th, 1917.



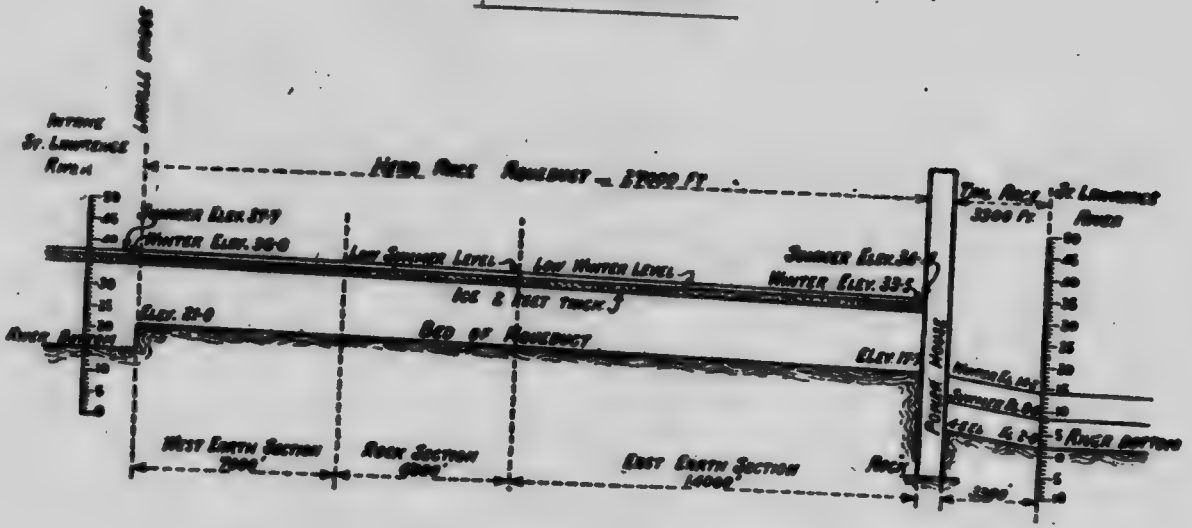
MONTREAL WATERWORKS AQUEDUCT ENLARGEMENT

PLAN ACCOMPANYING REPORT OF BOARD OF ENGINEERS DATED 30TH. APRIL, 1917.

MONTREAL WATERWORKS AQUEDUCT ENLARGEMENT

SCHEME NO. II.

PLAN ACCOMPANYING REPORT OF BOARD OF ENGINEERS DATED 20TH APRIL, 1917.

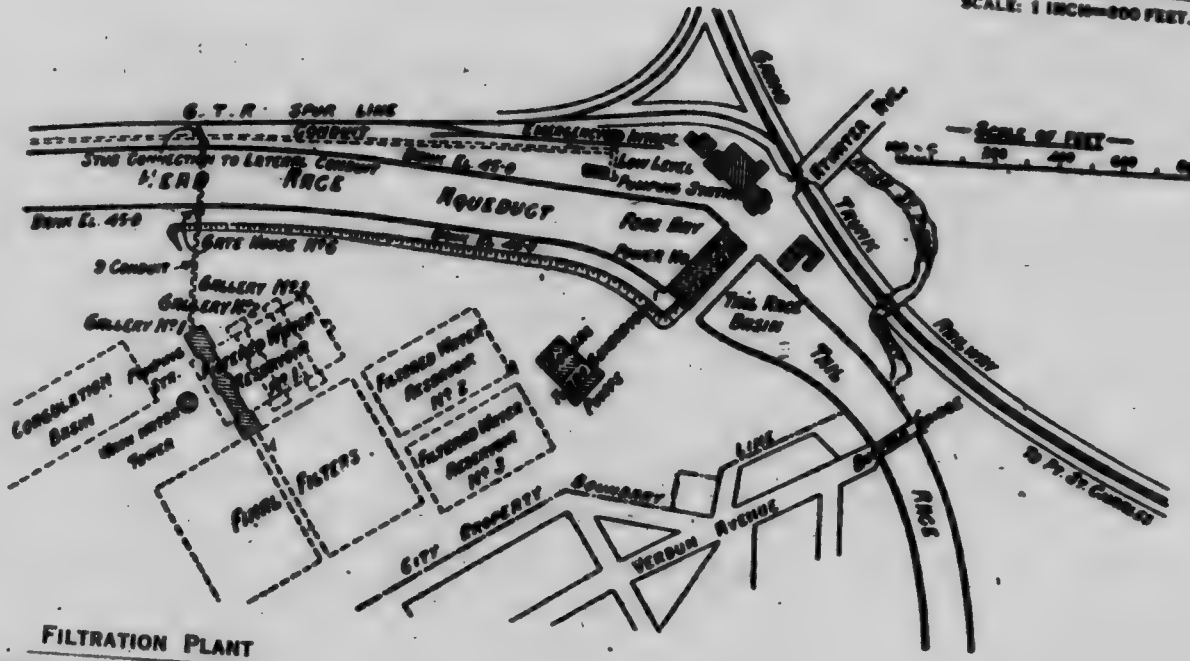


MONTREAL WATERWORKS AQUEDUCT ENLARGEMENT

SCHEME No. 1.

PLAN ACCOMPANYING REPORT OF BOARD OF ENGINEERS DATED 30TH APRIL, 1917.

SCALE: 1 INCH = 800 FEET.



FILTRATION PLANT

GALLERY No. 1. AS IT IS BUILT.
GALLERY No. 2. PROPOSED EXTENSION FOR 100 MILLION GALLONS.
GALLERY No 3. PROPOSED EXTENSION FOR 150 MILLION GALLONS.

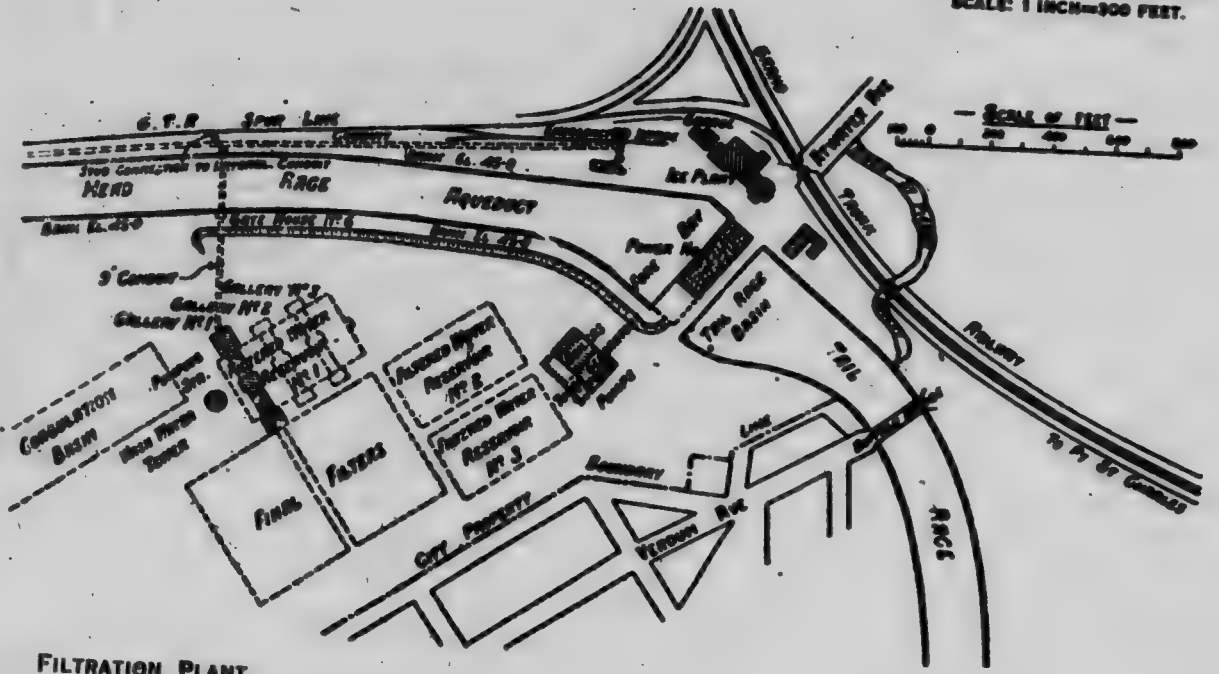
GALLERY No. 3. PROPOSED EXTENSION
FOR 150 MILLION GALLONS.

MONTREAL WATERWORKS AQUEDUCT ENLARGEMENT

SCHEME No. II.

PLAN ACCOMPANYING REPORT OF BOARD OF ENGINEERS DATED 30th APRIL, 1917.

SCALE: 1 INCH = 300 FEET.



FILTRATION PLANT

GALLERY No. 1. AS IT IS BUILT.
GALLERY No. 2. PROPOSED EXTENSION FOR 100 MILLION GALLONS.
GALLERY No. 3. PROPOSED EXTENSION FOR 150 MILLION GALLONS.

Montreal Waterworks
Aqueduct Enlargement
Water Consumption Data

Diagram showing Daily Pumpage as percentage of Yearly Average
Accompanying Report of Board of Engineers
Dated 30th April, 1917.

Note.-Yearly Average 54,689,468 Imperial Gallons=100 per cent.
Hourly Pumpage varies 35 per cent above yearly Average.

Note.--This Diagram is compiled from Records of Low Level Pumping Station.

LIST OF QUESTIONS SUBMITTED TO BOARD OF ENGINEERS AT CITY HALL, MONTREAL, JUNE 6th, 1917, TO OBTAIN VERBAL INFORMATION FROM THEM TO ELUCIDATE THEIR REPORT ON THE MUNICIPAL AQUEDUCT, TOGETHER WITH THEIR ANSWERS GIVEN AT THAT TIME.

1—Does the first paragraph of "Recommendations" (page 41 of Report) signify that Project No. II is the one which the Board of Engineers formally recommend as a justifiable and true economic solution of the Aqueduct proposition as it exists to-day?

Ans.—No.

2—Is it not a fact that the Board recommend that no work be done in the tail race, that the plans for the hydro-electric power house should not be started, and that no work should be done in the head race rock section and easterly earth section, until a final decision has been reached and the source of power determined?

Ans.—Yes.

3—If a final decision has yet to be reached as to choice of a project, is it not a fact that none of the five projects considered by the experts has been recommended by them in their report?

Ans.—Yes, because it is impossible to recommend on account of contractor having to be dealt with.

4—If the Project No I or II is definitely recommended to us, why then does the Board of Engineers in contradiction to this, recommend that tenders be called for the purchase of power, and intimate in Article 3 of Recommendations that the source of power is yet to be determined?

Ans.—The Board of Engineers cannot recommend any of the projects because they have no figures to go on from Contractors. Wrote to Power Companies according to instructions from Mr. Villeneuve. When we have figures from Power Co. and contractors will then be able to form an opinion.

5—In Article 3 of Recommendations which of the five projects is referred to in speaking of changes and additions to the present contract (Cook Construction Co) for which the experts recommend us to ask tenders from the Contractor? What are the changes and additions referred to?

Ans.—Paving of head race—extra six inches of concrete, and enlargement of tail race.

6—Why, in Recommendation 4, does the Board say that we should buy immediately the lands required; if a decision has yet to be made, and if we do not know yet whether the power is to be bought, generated by steam, or produced from the aqueduct? What lands are referred to? For which projects are lands necessary and how much?

Ans.—Land will be required for each case and should be secured right away. More land required for Scheme II—other schemes no boulevards.

7—(a) Has the Board verified all estimates of cost included in their report? (b) Have any figures supplied by the city staff, been adopted without checking?

(c) Is the Board prepared to say definitely that all work necessary to complete the various projects can be done for the estimates given?

Ans.—(a) Yes. (b) They were checked in so far as possible. (c) No, it cannot be done for the estimates given inasmuch as the prices have changed and are subject to change from day to day.

8—Should not the cost of the lengthening of the guard pier be added to the capital cost of projects No. I, II and III, and omitted from projects IV and V?

Ans.—No. No guard pier required. Later on when the scheme has been put into operation, the engineer of the city will be in a position to judge if it is advantageous for the city to extend the guard pier.

9—Why did the Board omit the cost of their bridges from the capital cost?

Ans.—Because it has nothing to do with the canal itself. Cheap bridges could be built as formerly.

10—Is it not strictly obligatory, and an elementary rule in financial and industrial projects for the construction of public works to charge to the capital cost the amount of interest on the sums expended on the works during the execution or installation of same?

Ans.—The report speaks for itself. We have added net charges.

11—Why did the Board recommend the paving of the head race even if it were used for water supply only, and power purchased or produced by steam?

Ans.—**Simply stated that where walls were built the bottom should be paved to protect the walls.**

12—Is this not saddling schemes Nos. IV and V with an unnecessary expenditure?

Ans.—**Previous answer applies.**

13—Did the Board include this cost in the capital cost of schemes I, II and III?

Ans.—**Yes.**

14—What the "different assumptions of the quantity of power and the different methods for utilising said power" which the experts at page 37 of their report attribute to the Engineer in Chief, in comparing his figures to their own assumptions?

Ans.—**Quantities of power were not the same. Sloping of banks (Answer incomplete).**

15—Was not pumping by steam, or by electric power purchased, in 1907, and even in 1913, before undertaking the works of the second enlargement, the only real economic solution of the problem, as compared with the cost of installation and the operating cost and of the financial charges which would accrue through the present development of hydraulic power at the aqueduct?

Ans.—**We dont know what the situation was at the time.**

16—An average comsumption of 100,000,000 I. G. per 24 hours will not be required for many years, so that the amount of 8,570 H.-P. will be only required in the distant future. Where then is the financial benefit or the economy for the ratepayers in executing project No. II, which will give us surplus power which we cannot use for pumping for a number of years, and will also increase the capital cost over present requirements by at least two millions dollars, according to the figures of the report; will not the return still be disproportionate to the problematical advantages that have been suggested (the manufacture of ice)?

Ans.—**Necessary to look ahead many years because power, electric or steam, will increase—40 to 50 years.**

17—Which of the five projects is the one which the experts take the responsibility of recommending for execution?

Ans.—**After we have figures from the Power Companies and Contractors we will be in a position to recommend a project definitely.**

18—The Board under the title "Recommendations" hints that the possible claim of the Cook Construction Company is the only reason which prevents it from recommending scheme II, which they declare is the cheapest per horse-power year? Does not this claim equally affect all schemes?

Ans.—**No—Ask the electric company to give figures, if we had these figures would not hesitate to recommend.**

(Note.—Board's report, page 10, says:—"Contractors' Claims—These being the same for all five cases, have not been included".)

19—What has been considered "as the near future" by the Board when they refer on page 22, par. 4, to the probable time when the city will require to pump 100,000,000 I. G. for daily domestic supply?

Ans.—**Nine to ten years.**

20—If we add to capital cost the items I claim, on page 4 of my Commentary, viz. $4,476,143., what would then be the cost per H.-P. in projects I and II?

No answer given.

Note:—This report was addressed to Mr. Hirsch, President of the Canadian Manufacturers' Association, following the appearance of a delegation of ratepayers of Montreal at City Hall, demanding an inquiry and protesting against the aqueduct development.

DIRECTION OF PULBIC WORKS

CHIEF ENGINEER'S OFFICE

Mr. Michael Hirsch, June 26th, 1916.
Manager, Messrs. J. Hirsch & Sons, Ltd.,
62 McGill Street, Montreal.

Dear Sir:

I was told by Controller Coté to send you all possible information on the proposed 10,000 horse-power development.

This proposal must be taken as found by Controller Coté in 1914.

You came to the City Hall on Thurday the 22nd. instant with several citizens, to advise the City on the necessity of engaging outside engineers to report on that power development. You and others were convinced that outside engineers could report on the advisability, possibility and economical value of this power development.

You are probably not aware that the City has, from time to time, engaged outside experts to report on the same question.

POSSIBILITY.—Several reports were made to the City by engineers, such as Messrs. T. C. Keefer (1868), W. J. McAlpine (1869), Walter Shanly and James B. Francis. Those are old reports, but may be summarised as done by Alderman Rodden in 1869:—

"It may be said in reference to such a proceeding, that whatever is expended on the new entrance and the reservoir may fairly be considered as part of a reliable project for future completion, and good value for the cost as far as it goes. Putting up a second engine should not be entertained hastily; all other available means should be first exhausted. With the rapids of the St. Lawrence at hand there should not be any further necessity for steam power."

In March 1894, Messrs. Keefer and Vanier reported to the City:—

"Enough has been written to show that the aqueduct is, in every respect, a good property."

In the same report, page 11, we find the following:—

"The completion of this work will dispense with steam power in winter as well as summer, and will be worth the cost before the daily consumption of water reaches about 25,000,000 gallons."

On page 10:—

"The summer power of this aqueduct will range between 4,000 and 5.000 horse-power; and with the maximum of 3 feet thickness of surface ice at low water in winter."

Still later, in 1907, Mr. Ernest Marceau and Sir John Kennedy reported on the possibility of this power development:—

"We are of opinion that the projected works will supply water power to pump to the City 50,000,000 Imperial gallons per day of 24 hours under the most unfavourable conditions, that is, at the **lowest** recorded stage of the river in winter, and when the aqueduct is covered with ice, which is the capacity stated in Mr. Janin's reports."

and further:—

"Mr. Janin, in his report of March 18th, 1907, states that the enlarged aqueduct will develop 5,000 horse-power in winter. We are of the opinion that this estimate of power is correct for the most unfavourable summer conditions, that is, the enlarged aqueduct will furnish water to develop five thousand **effective** horse-power at the water wheels when the river at the entrance of the aqueduct is at its lowest recorded depth of 35.85 above datum. Under ordinary summer conditions, that is, with higher water the power which can be developed will, of course, exceed 5,000 horse-power."

On July 2nd, 1910, Messrs. Hering and Fuller reported as follows:—

"Our computations show that on a reasonable assumption the horse-power available in warm weather, measured on the shaft, as above stated, will be practically double that available during the most unfavourable winter conditions, or about 5,000 horse-power. This should be available about nine months each year."

Those reports, from outside engineers, corroborate the City Engineer's reports.

Before closing the remarks on this part of the question, I would point out one special case where the City was advised to engage outside experts.

During the construction of the filtration plant, the City was asked by the Montreal papers and prominent citizens, to appoint outside engineers to report on the subsoil on which this building was being erected. This subsoil according to these critics, was inadequate for such work and "it would be laughable and farcical if it were not so pathetic to see a building like the proposed filtration plant erected on such foundations." (W. J. Francis—"Montreal Herald", May 23rd, 1913.)

The City received from Messrs. Jamieson, St. George and Barbeau, the following approval on the work recommended by its engineers:—

"That the soil has, and will have under operating conditions sufficient bearing capacity to support the loads to be imposed."

The only difference made in the filtration plant by these critics was to add some $15,000.00 to the cost of the plant: the amount of the experts' fees.

I do not think that any engineer will venture to say that the City cannot produce a 10,000 horse-power plant in drawing enough water from the St. Lawrance, under conditions similar to those which Messrs. Marceau and Kennedy stated would produce a minimum of 5,000 horse-power.

FRAZIL.—You were also told that because the Lachine Hydraulic had trouble with frazil, the City will also have the same trouble. You were not told that no frazil was found in the Lachine Canal: the Lachine Canal is as close to the proposed aqueduct, but this was not mentioned to you for obvious reasons.

The question of frazil was taken up by outside engineers, and they reported as follows:—

"There is no evidence in this, or from any reported examination by him (A. Davis) of the aqueduct, that the low water was caused by anchor ice. Since the new entrance was completed in 1877, we can find no reference to any trouble from anchor ice in the annual reports."

"But, as an evidence that the reduced water power of the winter months is due entirely to low water and thickness of surface ice, and the diminished water section caused by these and not by anchor ice, it is only necessary to point to....."

"All the engineers—Messrs. Francis, Shanly, McAlpine—have reported that all that was required to get rid of the ice difficulties in the aqueduct was increased size of water way, and as to the practicability of winter water power it is only necessary to refer to the Lachine Canal....."(Keefer and Vanier—March 1894.)

The question of frasil was reported upon by Messrs. Marceau and Kennedy in 1907, as follows:—

"The details of the works at the entrance of the aqueduct and the intake of the conduit are not yet fully worked out, but from the fact that the position of the present aqueduct intake is a very favourable one, and that no trouble has ever been experienced form frasil entering it, we are of opinion that the works can be so designed and built, that their operation will not be seriously interfered with by frasil."

COST OF POWER.—You were also told that the cost per horse-power would reach $700.00 and that it was "horrible" to just think of it.

Outside engineers would not recommend an "horrible" expenditure. Would they not?

The old aqueduct developed 400 to 600 horse-power, at a total cost of $500,000.00, or $833.00 per horse-power. No outside engineer has criticised the cost of this power.

Messrs. Marceau and Kennedy were asked, in 1907, if the proposed enlargement would produce 5,000 horse-power, and they answered that this would be produced at a total cost of $2,200,000.00, or $733.00 per unit.

Messrs. Hering and Fuller reported in 1910 on the power canal:—

"This water power development is a sound practical business proposition on its own merits and there should be no concern felt on the part of taxpayers as to the wisdom of expenditures for this improvement."

Has any one of these outside engineers stated, when engaged by the City to report on the proposed water power development, that the cost per horse-power was just "horrible"? None ever questioned the unit cost until the fall 1915.

The total cost of the water development has been placed at different figures: $7,000,000.00, $9,000,000.00, and even $14,000,000.00.

The $14,000,000.00 is arrived at by adding together the costs of proposed works and future extension works, including filtration and conduit.

The $9,000,000.00 is arrived at by adding together all the costs of works assumed to be required for the water power development, the cost of the filtration plant, the cost of the conduit and incidentals therefrom.

The $7,000,000.00 is arrived at by adding together all the costs of the works mentioned for the cost of $9,000,000.00 less the cost of the filtration plant.

WHAT THE COST WILL REALLY BE

Any person will admit that, with or without power development, the city must fence its property, dig out the necessary drains and provide an outlet for these drains; this is to be done for the sum of $75,000.00.

On walking along the side of the actual canal, you will no doudt notice that existing bridges are in need of repairs, especially Church and Buffalo, Lasalle Road and Wellington Street bridges must be remodelled so as to meet the increase of the traffic. The other bridges must be built so long as there is a canal, with or without power. The cost of these bridges will amount to $560,000.00.

You are probably aware that there are no regulationg gates at the entrance of the canal, only an earth dam. The City was advised to build these regulating gates as soon as possible. (See report of Messrs. Jamieson, Lea and Heckle, dated February 21st, 1914—page 21.) We have estimated the cost of these gates at $100,000.00.

The boulevards were not considered to be inherent for the water development. The cost of the excavation was reduced by $100,000.00 because of the facilities given for the disposal of the excavated material.

It has been found by experts who discussed the matter with me, that the north wall, protecting the shore where the conduit is, should be rushed through, as it is of absolute necessity. The south shore of the canal cannot be left as it is, being vertical, and in danger of sliding.

The City has proposed the construction of a concrete wall to protect the south bank, but outside engineers thought that a cheaper way would be to just slope the bank to its natural angle of repose. The difference between the two proposals is of about $100,000.00. The sloping of the ground will require more land, and the removal of earth already excavated and placed on the bank.

The lateral conduit already constructed can deliver some 80,000,000 gallons daily.

When the 100,000,000 gallons are needed, it will be necessary to fill the canal with water or build another conduit in the south bank.

The cost of the former project will be nil if the south wall and head gates are already built. The cost of the latter project will reach $1,000,000.00.

We have, therefore, the following costs:—

Bridges	$560,000.00	
Fences and ditches	60,000.00	
Culverts	15,000.00	
Land for Boulevards	112,500.00	
North wall	975,000.00	
South wall (or slopes)	975,000.00	
Head gates	100,000.00	$2,797,500.00

which may or may not be charged against the water development, but which must be done, as explained, whether the water power is developed or not.

The City has, therefore, a canal, filled with water, ending by a solid wall, on the east side of which there is a head of 16 to 22 feet. It was therefore, natural for the City engineers to think of using this idle force and produce the power necessary to pump 100,000,000 gallons daily.

To do this, it is necessary to enlarge the head race and the tail race, build the pump-house, the estimate of which would be:—

Enlargement of head race	$457,800.00	
Enlargement of tail race	180,000.00	
Pump-house	980,000.00	
		$1,617,800.00

In 1913, it was thought advisable to enlarge the power plant and to produce with it some 4,000 electrical horse-power, which the City could use as it saw fit.

The cost of this extension would be:—

Additional enlargement of head race	$306,000.00	
Additional enlargement of tail race	120,000.00	
Power house (4,000 horse-power)	400,000.00	
		$826,000.00
The total cost of these two projects would be		$2,443,800.00

In this letter I have always referred to a 10,000 horse-power. This 10,000 horse-power will be produced when the water is at its lowest stage and when the canal is covered with 2 feet of ice. This lowest stage of water has not occurred in the last twenty years, but was observed in the sixties.

Supposing this condition to exist for a period of three months, the power will be much greater the balance of the year. The average for the year may be estimated at 14,000 horse-power, and even this will be a low figure. This would bring the cost per unit to $175.00.

You have also heard of a pier to be built at the entrance of the canal at a cost of $475,000.00 and that this pier was to be entirely charged to the water development. The construction of this pier will increase the head at the power house by 2 feet and power produced will be increased proportionately. The cost per unit will, therefore, remain the same.

COST PER HORSE-POWER

The cost per horse-power will, therefore, be:—

Interest on $2,443,800.00 at 4½%	$109,710.00	
Sinking fund	17,585.00	
Cost of operation	11,700.00	
Wages	16,000.00	
		$154,995.00

Say—$160,000.00 for the total cost and that the power produced will be only 12,000 horse-power:—

The cost per unit would be $13.33

ACTUAL COST OF

The cost of pumping 1,000,000 gallons per day is $8.77, if we assumed that the 30,000,000 gallons DeLaval pump is the standard of our steam plant, which is not the case.

For a daily consumption of 100,000,000 gallons per day, the cost would be $877.00 per day, or $320,000.00 per year, which represents twice the amount mentioned as the total cost of 12,000 horse-power.

It was also advised that the City could save money in buying its electricity at the local rates. The cost to the City would be:—

6,000 H. P. 24 hours at $30.00	$180,000.00	
4,000 H. P. 12 hours at 20.00	80,000.00	
		$260,000.00

This amount is still greater than the cost of the water power as mentioned above.

To the cost of electric horse-power purchased at $30.00, the wages of electricians, oilers and helpers, the sinking fund on the pumps, motors, buildings etc., and the interest on the capital invested must be charged against the horse-power. This would amount to:—

Interest	$25,000.00	
Operation and maintenance	5,500.00	
Wages	8,000.00	$38,500.00
or per horse-power	6.41	

We have been told that the City could buy electric horse-power at at the rate of $12.00 for 24 hours' operation; even at this extraordinarily low cost, we would still have the following cost per unit—

Cost of horse-power.....	$12.00	$18.41
Operation, interest etc.....	6.41	

We have, therefore, the following cost per unit:—

Steam plant horse-power.....	$55.33
Electricity purchased h. p. $30.	36.41
Electricity purchased h. p. at $12...	18.41
Water power as proposed.....	13.33

Yours very truly.

(Signed) PAUL-E. MERCIER
Chief Engineer and City Surveyor

OPPORTUNITY TO COMPLETE THE AQUEDUCT ENLARGEMENT
No. 20207.

CITY HALL

PUBLIC WORKS DEPARTMENT

CHIEF ENGINEER'S OFFICE

Montreal, December 16th, 1916.

To the Chairman and Members
of the Board of Commissioners.

Gentlemen,—

The Ratepaying Engineers' Report received by your Board on November 20th, has been sent to me for report.

The Conclusions of the Ratepaying Engineers are that the City should abandon all work in connection with the aqueduct enlargement, because:

(a) The project as designed will not develop more than 7,000 electrical horse-power;

(b) The frasil may cause complete stoppage of the plant during a certain period;

(c) It will be cheaper to purchase electric energy than to operate the proposed development.

From time to time, well-known Engineers have been asked by the City for technical advice on developing its own water power. None of these Engineers ever questioned this principle, but always reported that it would be to the City's advantage to build and operate its own water power, even when there was electric energy for sale in Montreal.

In 1910 the City was advised by its Chief Engineer, the late Mr. Janin, to increase its water power to 10,000 h.-p. The City's intentions were made known to the public by the local press. Years after, when more than half of the proposed work has been done, the City is advised to abandon the project.

ESTIMATED HORSE-POWER

Before the Ratepaying Engineers Report was sent to your Board, the probable horse-power obtainable from the enlargement had already been carefully studied by your Engineers.

After locating the low period, Mr. Dorrance assisted by Mr. Vallieres, under the direction of Mr. Field and Mr. LeSage, made a day-by-day study of the water power that could be produced during that low water period, using water-gauge readings for a period of nineteen (19) years.

Even in assuming worse climatological conditions than generally existing on the Island of Montreal, and not considering the increase in head that would be produced by the proposed break-water, the figures found by your Engineers are greater than those given by the Ratepaying Engineers.

It was ascertained by your Engineers that the theoretical water horse-power was less than 13,000 for only one day during the nineteen (19) years.

That the average during the low period would be between 15,500 and 20,500, the mean value being about 18,000 h.-p.

It was also found that the water horse-power was less than 15,000 h.-p. for a period not exceeding 100 days in one year.

FRAZIL

Although reports made by Messrs. Keefer and Vanier, by Messrs. Marceau & Kennedy, and a paper read by the late Mr. Janin, proved that frazil never affected the old City water development, it is claimed by the Ratepaying Engineers that "Frazil may cause complete stoppage of the plant". Among the signatures to the Ratepaying Engineers Report, are found those of Engineers who sent to the City in 1907, a report stating that "the frazil will have no material effect on the plant".

COMPARISON OF THE TWO PROJECTS

If the enlargement be stopped and the City purchase the required electric energy to pump the water and for the lighting of its streets and buildings, it will cost the City **$827,857.00 per year.**

If the work is completed and the excess power used as required in the City's shops, pumping stations, etc., and for the lighting of its streets and buildings, it will cost the City **$760,082.00 per year** and the City will own its street lighting system.

It will also be possible, if the work is completed, for the City to sell

some 5,000 h.-p. during seven months per year, at $15.00 per h.-p. This would give the City a yearly revenue of **$75,000.00.**

In this comparison the cost of electric energy to be purchased as recommended by the Ratepaying Engineers, has been estimated at $25.00 per h.-p. for twenty-four (24) hours service.

WHO CAN STATE WHAT THE CITY WOULD HAVE TO PAY FOR ELECTRIC ENERGY IN 1920?

AS A MATTER OF FACT, THE MARKETS FOR THE POWER HAVE DEVELOPED SO RAPIDLY THAT THE COMMISSION HAS BEEN COMPELLED, EARLIER THAN WAS ANTICIPATED, TO SEEK DILIGENTLY FOR NEW SOURCES OF POWER".

(Seventh Annual Report, Commission of Conservation, Canada, 1916.)

There will be, before long, such a call for electric energy that the production will not meet the demand.

The City cannot afford to gamble on the problematic future cost of electric energy, when it can, at the actual market prices, have its own water power and street lighting system, at a lower cost or even at the same cost, and be totally independent of any problematic future trust.

As it is to the advantage of the City to complete the proposed 10,000 h.-p. development, this should be done.

I have the honour to recommend that your Board engage the necessary export to design the power house, call tenders for its construction and that of the bridges immediately, settle the pending difficulties with the Contractors, and complete the work as soon as possible.

CONCLUSIONS:

The conclusions of my report are in complete contradiction with those of the Ratepaying Engineers. As the Ratepaying Engineers Report was given a large publicity, it would be advisable for your Board to ask three experts to examine both and report thereon.

I would recommend to your Board to seek the advice of two Engineers, who have never before reported on the aqueduct enlargement, and of one wellknown business man.

Respectfully submitted,

(Signed) PAUL E. MERCIER,
Chief Engineer and City Surveyor.

PEM/McL.